

247 p.

# **PROCEEDINGS OF THE SPACE SHUTTLE SORTIE WORKSHOP**

## **VOLUME I POLICY & SYSTEM CHARACTERISTICS**

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**JULY 31—AUGUST 4, 1972**

**NATIONAL AERONAUTICS & SPACE ADMINISTRATION  
GODDARD SPACE FLIGHT CENTER  
GREENBELT, MARYLAND**

NASA SPACE SHUTTLE SORTIE WORKSHOP

SPONSORED BY THE  
OFFICE OF SPACE SCIENCE  
AND  
OFFICE OF APPLICATIONS

SUPPORTED BY THE  
OFFICE OF MANNED SPACE FLIGHT

HOSTED BY THE  
GODDARD SPACE FLIGHT CENTER

Dr. Rodney W. Johnson, Headquarters  
GENERAL CHAIRMAN

Dr. Leslie Meredith, GSFC  
CO-CHAIRMAN



## FOREWORD

As the National Aeronautics and Space Administration moves into the design and development phase of the space shuttle, it is necessary that the Agency further definitize planning for utilization of the shuttle. In recognition of this need, it was determined that a workshop should be conducted for NASA scientists and technologists.

NASA conducted this Space Shuttle Sortie Workshop at the Goddard Space Flight Center during the week of July 31 to August 4, 1972. For the purposes of this workshop, shuttle sortie missions were defined as including those shuttle missions which employ observations or operations (1) from the shuttle itself, (2) with subsatellites of the shuttle, or (3) with shuttle deployed automated spacecraft having unattended lifetimes of less than about half a year.

In general, the workshop was directed towards the education of selected scientists and other personnel within NASA on the basic capabilities of the shuttle sortie mode and the further definition of how the sortie mode of operation could benefit particular disciplines. The specific workshop objectives included:

- Informing potential NASA users of the present sortie mode characteristics and capabilities
- Informing shuttle developers of user desires and requirements
- An initial assessment of the potential role of the sortie mode in each of the several NASA discipline programs
- The identification of specific sortie missions with their characteristics and requirements
- The identification of the policies and procedures which must be changed or instituted to fully exploit the potential of the sortie mode
- Determining the next series of steps required to plan and implement sortie mode missions.

To accomplish these objectives fifteen discipline working groups were established with Headquarters' Chairmen and Center Co-Chairmen, (Appendix A). Well before the workshop, each working group was furnished an outline of the data they were expected to produce as a result of the workshop (Appendix B).

Several groups held individual preliminary meetings to organize their efforts. The workshop agenda (Appendix C) was structured to give these working groups a management overview of the shuttle program, the current status of the shuttle sortie mode planning, and an opportunity to discuss the results of their efforts both with the people responsible for the shuttle systems and with the members of the other working groups. To encourage meaningful dialogues between the participants, this was done in a workshop environment. To this end attendance was limited to about 200 and was by invitation only. Of these participants (representing all NASA Centers) 145 were working group members and the remainder were speakers and observers.

From the reports which are contained in the two volumes of this document, it is apparent that the workshop met its objectives. Not as apparent, is the spirit of cooperation and enthusiasm generated among the participants.

At the final workshop session it was agreed to follow up and further definitize the accomplishments of this workshop by a number of actions. These included broadening the working group membership to be representative of the total user community and the adoption of the schedule of events outlined in Appendix D.

It is apparent that the activities set in motion with this workshop are tasks of considerable magnitude. Traditional methods used to conduct mission and payload planning for advanced missions need to be improved upon for shuttle missions. As Dr. Naugle states in a policy paper contained in this volume "We are beginning the process that will lead to the people, the policies, the procedures, and the hardware that we will use to conduct scientific research in space in the decade of the 1980's."

The Co-Chairmen would like to take this opportunity to sincerely thank all the participants for their cooperation, understanding, and contributions which directly led to the success of the workshop.

R. Johnson — General Chairman  
L. Meredith — Co-Chairman

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## WELCOME

Donald P. Hearth  
Deputy Director  
Goddard Space Flight Center

I'm substituting today for John Clark who unfortunately could not be with us. In a way I'm pleased that he's gone because it gives me the opportunity to personally talk with you.

I want to welcome you all to Goddard and particularly welcome George Low, Deputy Administrator, John Naugle, Associate Administrator for Space Science and Chuck Mathews, Associate Administrator for Applications, who will be here shortly. I understand all centers are represented and I especially wish to welcome the speakers and the working group members because only they can make this meeting a success. To this end we've tried to make the necessary support available but if additional support is desired we urge you to let us know.

This is an excellent time for the meeting in many respects. From the Center's standpoint we are now between launches of our two most important missions this year. A week ago yesterday, ERTS-A was launched and "ERTS the First", as it's being called, is operating very well. The data is of excellent quality. Three weeks from today we will launch OAO-C, the last of the OAO family and our most complicated space science mission of the year. Missions such as those allow us to confidently plan for the future. We at Goddard look forward to using the shuttle for many of these future missions including those requiring looking back to the earth as well as those requiring looking up to the stars.

From the standpoint of the shuttle's program timing, the selection of the contractor was announced last week so it's timely from that point of view; and, as Rod suggested in his comments, it's early enough in the shuttle program to have the experiment planning influence the shuttle and its interfaces with the experiments.

Ladies and gentlemen, I'm delighted to have you here and wish you good luck in the meeting and we look forward to substantive results. Thank you.

SECTION 1

POLICY PAPERS

Presented by

Dr. George M. Low, NASA Hq.

Dr. John E. Naugle, NASA Hq.

Mr. Charles W. Mathews, NASA Hq.

at the

Proceedings

of the

Space Shuttle Workshop

July 31-August 4, 1972

KEYNOTE ADDRESS  
SHUTTLE SORTIE WORKSHOP  
JULY 31, 1972

Dr. GEORGE M. LOW  
Deputy Administrator  
NASA

Good morning. I would like to add my words of welcome on behalf of all of NASA. You are here to begin an activity of the highest importance — NASA's future, and indeed the United States' future in space depends a great deal on how well you will do your job.

Our space program is at a turning point. There is much to be done — we are at the threshold of new discoveries in science, and many practical applications are within our reach, yet our resources are limited. We can only do the things that we should do in space if we find new ways of doing more for less money. You have an opportunity, and a challenge to make this happen.

Let me first say a few words about the "state of NASA." Recently I have seen quite a few gloomy faces around the agency, but I think these faces reflect an attitude, and not really a thoughtful reflection. Let's take a look at the facts: it's true we have shrunk in size, and we cannot do all of the things we would like to do. But nevertheless, we have a sound program, both now and in the future. We have a strong program in SPACE SCIENCE, with exciting results from UHURU, Mariner 9, Apollo, and many others bringing us new fundamental knowledge every day. These will be followed by another OAO, by HEAO, and by a long string of major planetary programs — Pioneer (now on its way to Jupiter), Mariner Venus-Mercury, Viking, and Mariner Jupiter-Saturn.

Or let's take a look at SPACE APPLICATIONS. Here the big event of the year is ERTS, which has just opened a new age of space applications. Meanwhile, we are continuing our efforts in meteorology and communications with ITOS, TIROS N, Nimbus, and ATS.

In MANNED FLIGHT, we have Apollo 17, closely followed by Skylab. Both Apollo 17 and Skylab will make significant contributions to science and applications as well. Then there will be a major adventure in international cooperation: the Apollo-Soyuz Test Project.

Finally, or should I say last but not least, there is the space shuttle — a major new start for the space program. I won't list the shuttle under the category

"manned space flight" because it is much more than that. The purpose of the shuttle is to serve science and applications — to let us do more useful and necessary things in space at greatly reduced costs.

I have not said much about aeronautics, because in this workshop we are mostly interested in space. But NASA does have an important and expanding aeronautics program!

I hope you will all agree with me that the program I have just outlined is sound. Granted it is less than we would like to do, but it's all the nation can now afford! To put it another way, it is less than we would like to do because things are so expensive, and because we are working under very tight budgetary constraints. Now there is very little we can do about the budget — it is imposed by external forces; but there is a great deal we can do about costs! Doing something about the high cost of doing business in space is NASA's biggest challenge — and it is also the challenge of this workshop.

What are the principal ways to make this happen? In my opinion they are to take advantage of the relatively unconstrained weights and volumes which are becoming available.

- Warwick Electronics makes television sets for Sears, beats their Japanese competition, makes money, and has an excellent warranty record.
- The Ford Motor Company has gone to a system of "absolute cost controls" on many of their newest projects. Costs are estimated 3-4 years before production to within a few dollars — the error on the Pinto was considerably less than 1%. The result: a small American-made car, cheaper than the VW.

I also recently flew on the Convair 990 while an ocean color mission was underway. I won't say much more about that experience now since you will hear more about this airborne laboratory later. But, believe me, I was most impressed when I saw how well and how inexpensively a real applications mission could be carried out.

I have not yet reached the point where I can put all of this together into a new way of doing business for NASA. I am still learning, and the Tischler task force has only just started making its contribution. But I would like to make a few observations based on what I have seen and learned to date. I will split these into two categories: DESIGN and IMPLEMENTATION.



In the DESIGN phase, the following principles are important:

- DON'T REINVENT THE WHEEL — Use the best that is available from other programs. In all of the industries I have visited "not invented here" is unheard of. All tear down their competitor's product, study it, analyze it, cost it, and make use of the best ideas in it, so long as they do not violate patent rights.
- STANDARDIZE — This applies to parts, components, modules, sub-systems, and entire systems. Warwick Electronics has only two different chassis for its entire line of TV sets; and the left and right landing gear on the A-10 are identical!
- DESIGN TO MINIMIZE TESTING AND PAPERWORK — Note that I did not just say "minimize testing and paperwork"; I said DESIGN to achieve this. Simply stated this means: use larger margins and higher safety factors. In Apollo we spent millions of dollars — on tests and paper — to be sure we did not exceed the "fracture mechanics" limits on our pressure vessels. A few extra pounds in tank weights would have completely eliminated that problem, and the testing and paperwork along with it.
- KNOW YOUR COSTS — None of the things I have said so far has any meaning if you don't know how much each element costs. The area of accurate cost estimating is one where we have a great deal to learn.
- TRADE FEATURES FOR COST — This follows naturally from the previous item. Once we know how much something costs, then we can ask ourselves whether it is really worth it. Many of our so-called "requirements" really aren't that firm, and should be stated as "goals," to be reexamined in terms of cost.
- PAY PARTICULAR ATTENTION TO THE FEW VERY HIGH COST ITEMS — In many designs some small percentage of the items amount to most of the costs. By knowing the costs, and by listing items in order of descending costs, it becomes possible to devote a great deal of attention to the high cost items — generally with profound results.

In the IMPLEMENTATION phase, I would emphasize the following points:

- KNOW YOUR COSTS BEFORE YOU START — This perhaps is the most fundamental of all requirements. Without exception, the NASA programs which have been in difficulty were the ones that had insufficient definition at the outset.

- SET FIRM COST TARGETS — A desire for the "lowest possible cost" is not a good way to approach the job. A firm and absolute cost ceiling should be established for each job.
- MEET THE ESTABLISHED COST TARGETS — Don't blame cost growths above target on "external forces." Find ways to meet the targets, no matter what happens. This means that you have to become more productive in one area, if another area exhibits an "unavoidable" cost increase.

In summary, we must find ways to design for lower costs, we must know our costs, and we must set out to meet those costs. This works in successful firms in the commercial world, and there is no reason why it shouldn't work for NASA as well.

Above all, it takes a strong management interest to get this done. I hope I have by now demonstrated that NASA management is very interested!

Let me change the subject now, and briefly talk about another important area: USER INVOLVEMENT. This workshop is a good example of what I have in mind. You are here to discuss jointly what the shuttle — in the sortie mode — should be.

I particularly want to remind those from the manned space flight organization who are participating in this workshop that the only reason for developing a shuttle is to provide a service to all potential users. If it won't do that, then there is no point in building it.

This may require a new attitude on the part of some of us in NASA. Specifically, we must learn to give the user WHAT HE WANTS, and not WHAT WE THINK HE SHOULD WANT! I am sure that this workshop is the right first step in this direction.

Let me conclude by wishing you great success in the conduct of the workshop. As I said at the outset, what you are doing here is of first importance to NASA — because how much science and applications we will be able to do in the future depends on how well you set the stage in this meeting.

PROGRAM OVERVIEW  
SHUTTLE SORTIE WORKSHOP  
JULY 31, 1972

Dr. John E. Naugle  
Associate Administrator  
Office of Space Sciences, NASA Headquarters

Along with Don Hearth and George Low, I would also like to welcome you to the sortie workshop.

We've asked you to come here this week to begin a process that will ultimately lead to the people, the policies, procedures, and hardware that we will need to exploit the full potential of the sortie mode of the shuttle for science and applications.

This morning you are starting the same kind of process that we went through in the late 50's and early 60's to develop the concepts of OGO, Surveyor, Imp, OAO, Mariner, and establish the policies and procedures which we used to put those systems to work for scientists and engineers around the world.

As George has said so eloquently, NASA's fundamental objective is to accomplish the best science, exploration and applications program with the resources that we have. And it's become rather clear that there's a very finite ceiling to the resources that we have.

The shuttle and, in particular, the sortie mode of the shuttle can, we believe, if properly designed and operated, enable us to accomplish a great deal more with those resources. However, a capable and useful shuttle and the programs to exploit that capability will not just happen. A lot of us are going to have to work very hard to make it happen just as a lot of us had to work very hard to make OGO, OAO and Surveyor happen. The purpose of this workshop is to get the people who were developing the shuttle together with the people who will be using it to make sure that it does happen.

There are three things which I want to do this morning. First, I want to tell you what our current thinking is in the office of space science regarding the shuttle, what our plans and policies are for the use of the shuttle, and how the sortie mode of the shuttle fits into those plans.

Secondly, I will review our objectives for this sortie workshop, why it's being held, what we in the office of space science hope to accomplish — the questions we hope you will begin to answer over the next five days.

Finally, I will review the activity we have planned for the next year to build on the results of this workshop and further develop our plans for the use of the shuttle and the sortie mode.

These activities will extend the work you will be doing here by involving the non-NASA users of the sortie mode in our planning. And I want to emphasize that what I will propose will be a plan of action which has been prepared for your review, comment and modification. It can, should, and undoubtedly will be changed on the basis of the comments and recommendations that come from this workshop.

So now let me go directly to my first topic, our overall view of the shuttle, how we intend to use it for scientific research and the role we see for the sortie mode.

In our consideration of the shuttle, in order to develop our plans, allocate our resources and organize ourselves to use the shuttle, we have found it convenient to identify three separate and rather distinct modes in which we will use the shuttle at least for the first five to ten years of its operational life.

We have also identified these three modes to help us see where we can best use existing policies, procedures and organizations and where we have to develop new ways of doing business. Three modes are shown in Figure 1-1.

The first mode is simply as a first-stage booster to carry a conventional spacecraft and one or more additional propulsion stages into a parking orbit where the additional stages would be used to place the spacecraft into its desired orbit, whether this be a highly eccentric earth orbit to study the magnetosphere, or a geostationary orbit for a telescope or a trajectory to one of the planets.

And to give you a feel for this, Figure 1-2 shows how our largest spacecraft, Viking, and its propulsion system, Centaur, will fit into the cargo bay of the shuttle.

Figure 1-3 shows how a communications satellite on an Agena stage to place it into a geostationary orbit would fit into the shuttle.

Figure 1-4 is an attempt to assess the impact of this mode of the shuttle on some of the OSS activities of interest to scientists.

The use of the shuttle in this mode, where experiments and spacecraft must operate for a year or more unattended, is not likely to have a major impact on

- I. EARTH OR PARKING ORBIT BOOSTER
  - SPACECRAFT PLUS ONE OR MORE PROPULSION STAGES
  - GEOSTATIONARY, ECCENTRIC ORBITS AND PLANETARY MISSIONS
- II. ESTABLISH AND MAINTAIN AUTOMATED OBSERVATORIES IN SPACE
  - SPACECRAFT ONLY – NO ADDITIONAL PROPULSION OTHER THAN OMS
  - POLAR AND LOW INCLINATION, LOW ALTITUDE ORBITS
  - REPAIR, REPLACEMENT AND REFURBISHMENT OF COMPONENTS, SUBSYSTEMS, OR ENTIRE SPACECRAFT
  - LIFETIMES OF SPACECRAFT IN ORBIT – 10 YEARS
- III. SUPPORT A PROGRAM OF EXPLORATORY RESEARCH AND INSTRUMENT DEVELOPMENT – “SORTIE” MODE
  - INSTRUMENTS, EQUIPMENT – EXPERIMENTS – SCIENTISTS, ENGINEERS, TECHNICIANS
  - RESEARCH MAY BE MANNED, AUTOMATED OR A COMBINATION OF BOTH
  - 1-7 PAYLOAD SPECIALISTS – 1-30 DAYS IN ORBIT

Figure 1-1. Modes of Use of Shuttle, for Scientific Research

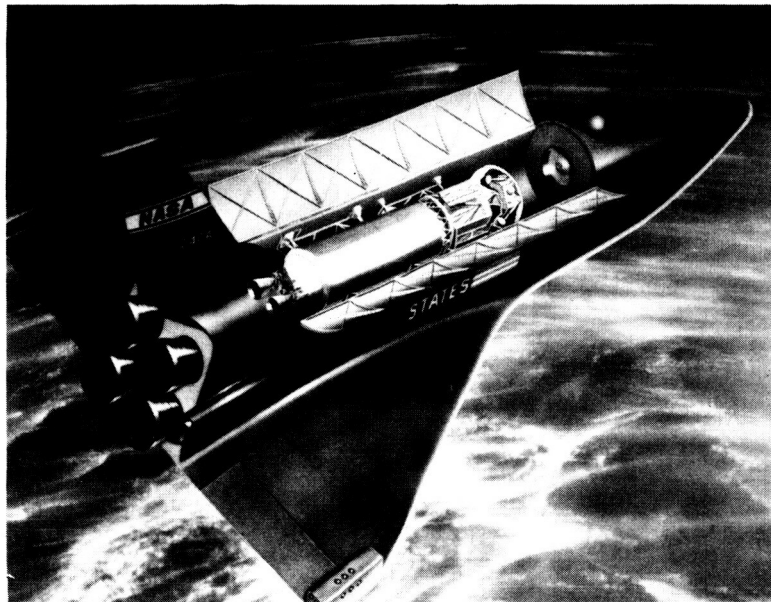


Figure 1-2

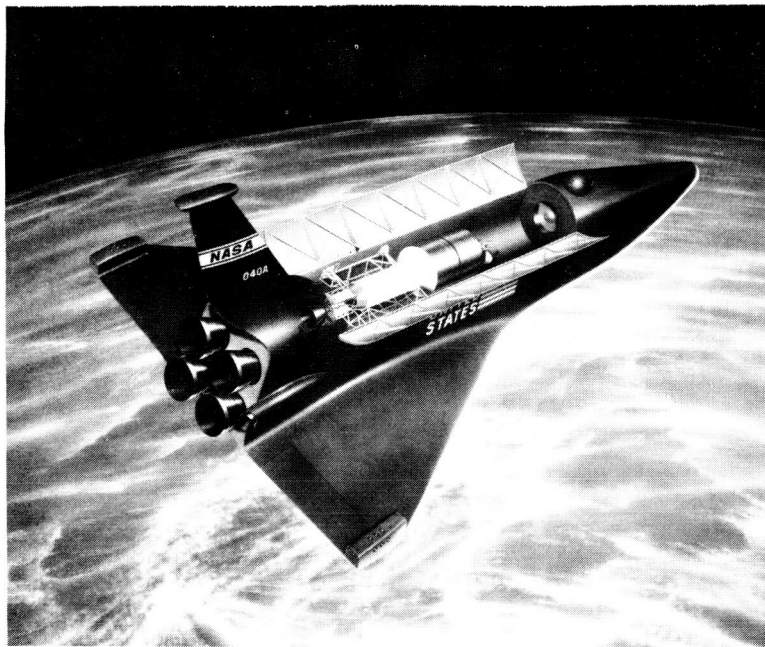


Figure 1-3

<u>ACTIVITY</u>	<u>IMPACT</u>
SR&T	NO CHANGE
PAYLOAD SELECTION	NO CHANGE
ROLE OF SCIENTISTS	NO CHANGE
TIME FROM CONEPT TO PUBLICATION	SLIGHTLY SHORTER
SPACECRAFT DESIGN & DEVELOPMENT	LOWER COST, LESS CONSTRAINTS ON WEIGHT AND VOLUME
SPACECRAFT OPERATION	NO CHANGE
REPAIR, REFURBISHMENT & RETRIEVAL	LIMITED W/O TUG

Figure 1-4. Impact of Mode 1 on OSS Activities

the way we do our business. We will continue to use our SR&T funds to develop new experimental concepts and to bring them up to the breadboard stage.

We will still need a carefully designed, reliable spacecraft, thoroughly tested out on the ground and experiments of similar reliability, carefully calibrated and designed to accomplish their objectives without further attention except for that which can be given over a telemetry link.

We think, however, that we will be able to reduce the cost of our spacecraft through a relaxation of the weight and volume constraints. There will be, as George Low indicated, changes from the way we have done business for the past decade by the time the shuttle becomes operational. We are already instituting some of those in HEAO and, of course, in Viking and we will be instituting others in the interim between now and the time the shuttle becomes operational.

I am referring to such things as doing more work to define and understand the experiments prior to committing them to a mission and then more insistence that once we have committed to a payload and selected a contractor to build that payload, that we promptly and expeditiously build and launch that payload and not slip schedules, change experiments, and otherwise do those things that delay the attainment of the data we seek and increase our costs.

I am also referring to the tendency to try to pack too many experiments aboard a given spacecraft with the attendant requirement to design something that looks more like a Swiss watch than a piece of innovative research hardware. This practice usually leads to a weight crisis about the time we have the maximum number of people working on the project whose salaries we have to pay while we go through an elaborate weight reduction exercise.

As George Low made abundantly clear, the reduction of the cost of doing business in space is a major objective of NASA line management; and he has discussed the task forces created under Del Tishler and I will not dwell on that.

More and more, the primary constraint on a given mission will be the resources that we initially allocate for that mission and more and more we will reward principal investigators, project managers and project scientists for their ability to extract the maximum return for the dollars allocated for a given mission rather than for their ability to squeeze the maximum return from the weight, power and volume available from a given launch vehicle.

The use of the shuttle in this first mode will enable us to eliminate the Thor, Atlas and Titan stages from our stable of launch vehicles. It will also give us

more capability to the geostationary orbit or to an escape trajectory. The present Titan Centaur can place about 3,600 kilograms in a geostationary orbit; a shuttle Centaur will be able to place about 6,000 kilograms in such an orbit or about a 70 percent increase in capability at about a 30 percent reduction of the recurring cost.

The elimination of three separate boosters and their replacement by a standardized reusable shuttle will reduce our transportation costs and ease our management load as well as significantly increase our overall probability of success.

In the second mode we will use the shuttle to establish and maintain permanent automated observatories in space. Generally, we would include any separable payload that does not require additional propulsion in this mode. However, for the purposes of this sortie workshop, we are including short-lived, six months or less, separable payloads in with the sortie mode. In this second mode, the shuttle can be used to place a spacecraft in orbit and then maintain it for a period of at least five to ten years by replacing major components or subsystems that have failed, by replacing experiments that have failed, completed their job or have become obsolete through scientific discoveries or by the advance of technology.

Figure 1-5 illustrates the use of the shuttle in this mode to support a large space telescope. The shuttle will place the observatory into the proper operating orbit. After a checkout to be sure that it is functioning properly, the shuttle will return to earth, leaving the observatory to be operated by a ground control center. Astronomers who wish to observe with the LST will come to the control center, develop their observing programs, which will be translated into commands to be sent to the spacecraft; the data will come to the astronomer at the control center. And, after a preliminary check to see that he has what he wants, then he will very likely return to his parent institution to analyze, interpret and publish the results.

If there is a malfunction or if an instrument or a detector needs to be replaced, the shuttle will return, rendezvous and either repair the observatory, replace the failed component or experiment, or, if necessary, bring the entire observatory back to earth for major repair or refurbishment.

This mode of operation of permanent observatories will have a substantial impact on the way we design, build, test and use our spacecraft. Figure 1-6 is another artist's conception of an LST and one of the modes that's under consideration of repairing and servicing an LST. In this case the shuttle



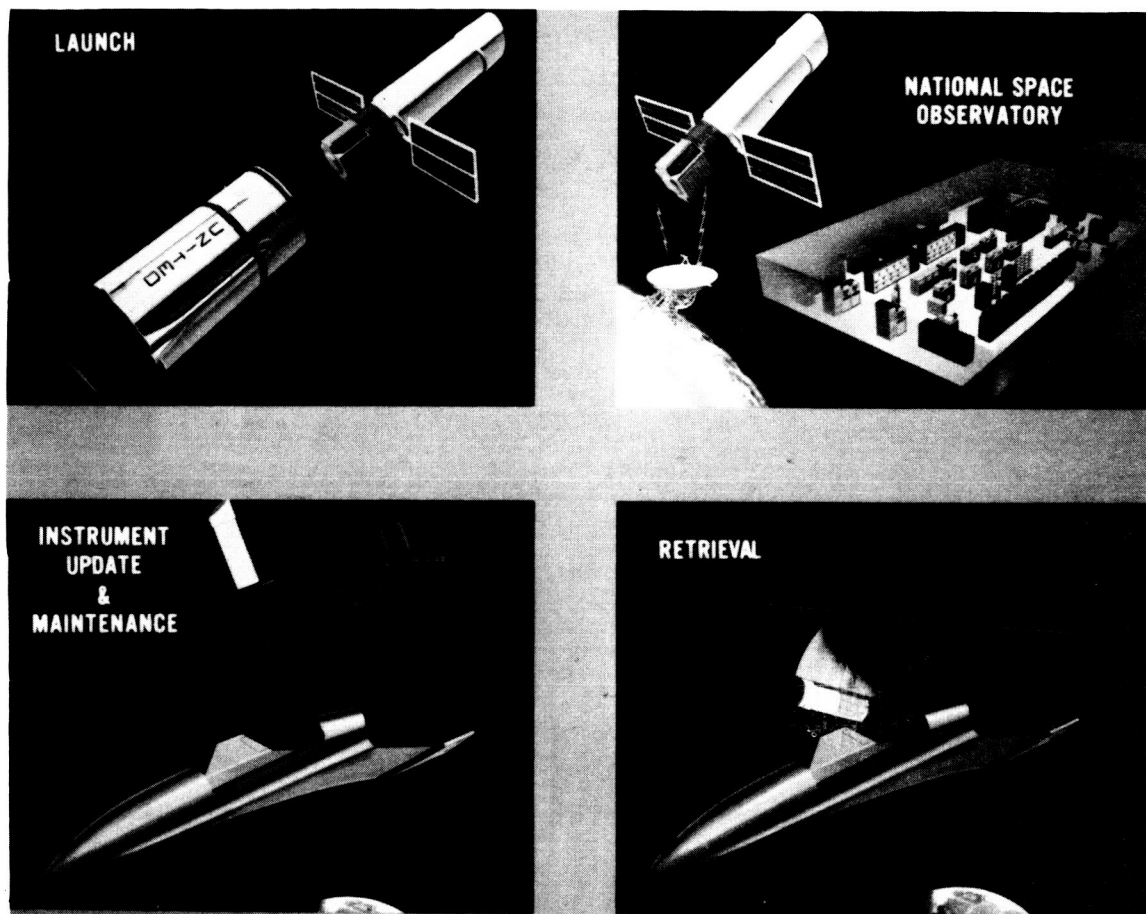


Figure 1-5

docks with the LST; you pressurize the back instrumentation compartment and then payload specialist would go up and work on the LST.

The other mode that's under consideration is a mode in which you would do this — you would still dock, but instead of having men go up you would use automated devices to replace entire black boxes, entire subsystems.

If I could go on then to Figure 1-7, we believe that there will be some shift in emphasis in our SR&T activity away from work leading to experimental hardware and instrument development and toward analysis, interpretation and theoretical studies. We will continue to need and to have a vigorous SR&T program, but in this area I believe there will be some change in emphasis.

There will be a major shift from the selection of individual experiments and experimenters to a selection of those who will use the facility. There will be a

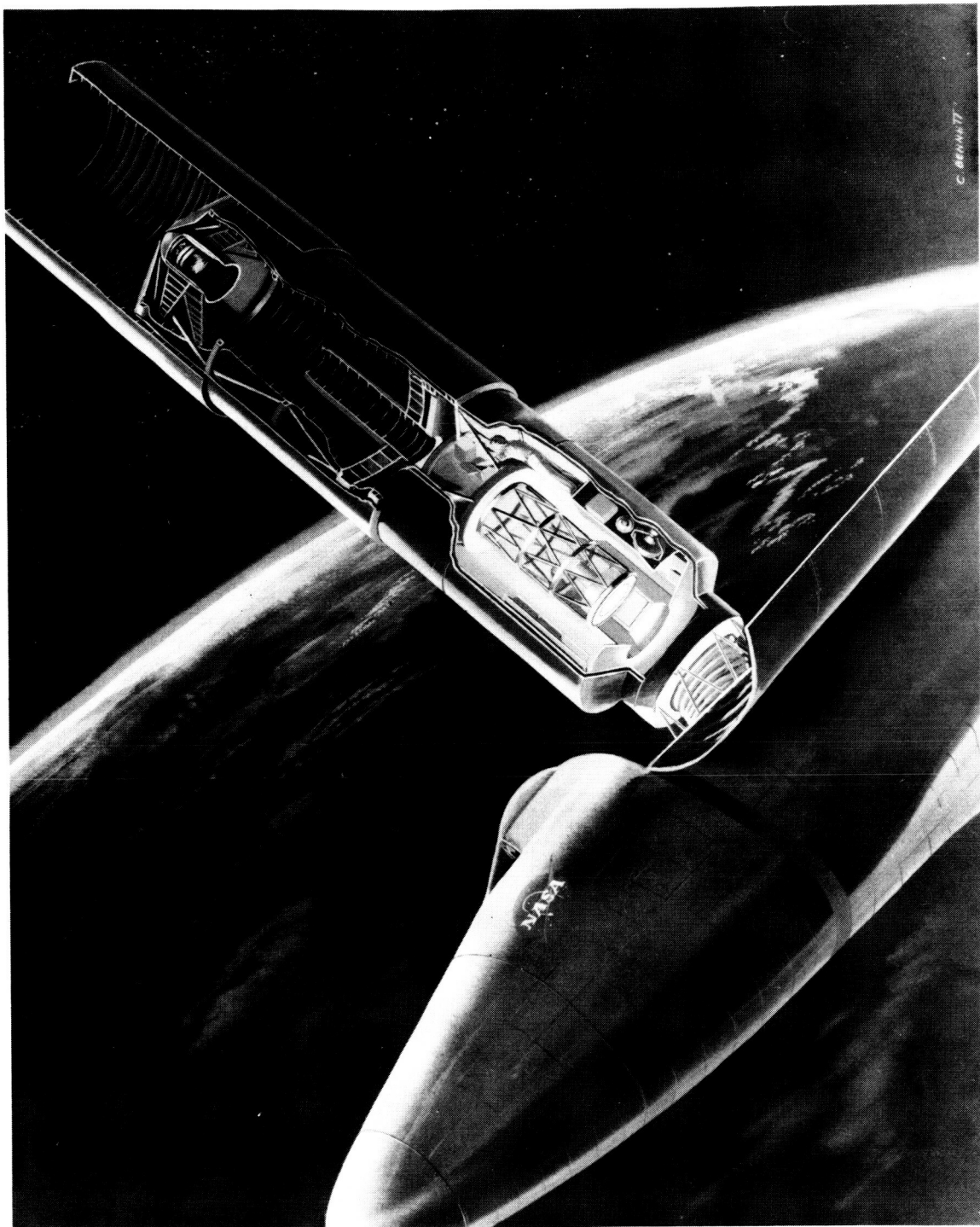


Figure 1-6

	<u>ACTIVITY</u>	<u>IMPACT</u>
SR&T		SHIFT IN EMPHASIS FROM EXPERIMENTAL HARDWARE AND INSTRUMENT DEVELOPMENT TO ANALYSIS INTERPRETATION AND THEORETICAL STUDIES
PAYLOAD		MAJOR SHIFT FROM SELECTION OF INDIVIDUAL EXPERIMENTS TO SELECTION OF USERS FOR A FACILITY
ROLE OF SCIENTISTS		MAJOR SHIFT FROM THE TRADITIONAL SPACE SCIENTIST ROLE DESIGNER, PRODUCER AND USER OF HIS OWN TO EXPERIMENTAL HARDWARE TO THE TRADITIONAL ASTRONOMER ROLE OF USER OF AN EXISTING ASTRONOMICAL FACILITY TO OBSERVE
TIME FROM CONCEPT TO PUBLICATION		SHOULD CONSIDERABLY SHORTEN THE TIME ONCE A FACILITY IS OPERATIONAL SINCE THE PRINCIPAL WAIT WILL BE FOR OBSERVING TIME NOT FOR THE DEVELOPMENT AND FLIGHT OF EXPERIMENTAL HARDWARE
SPACECRAFT DESIGN & DEVELOPMENT		MAJOR CHANGES
SPACECRAFT OPERATION		SIMILAR TO PRESENT OAO, BUT WITH INCREASED FACILITIES AND SUPPORT FOR USERS AND PRO- VISION FOR CONTINUOUS PERMANENT OPERATION OF A FACILITY FOR AT LEAST 10 YEARS
REPAIR, REFURBISHMENT & RETRIEVAL		MAJOR NEW AREA TO BE DEVELOPED

Figure 1-7. Impact of Mode II For Permanent Observatories (LST, HEAO-C)

major shift in the role of the scientist away from the traditional space scientist role of conceiver, designer and producer of his own experimental hardware and toward the more traditional astronomer role of using an existing astronomy facility to observe.

Scientists will still play the major role in defining the objectives, specifications and operating procedures for these observatories; but project teams will take on more of the heavy engineering developments for them.

Once such an observatory is installed in space, it should markedly shorten the time it takes a scientist to go from the concept of a new experiment through the acquisition of the data and the publication of the results. That time should primarily be determined by the length of the waiting list for observing time, provided, of course, we are smart enough to design into the observatory sufficient versatility and capability to satisfy the observing requirements of the astronomers for a substantial period of time.

The use of this mode will clearly result in major changes in the way we design, build and test our major spacecraft. While this use of the shuttle will introduce

major changes in the way we do business, we also feel that we are well on the way to making that transition.

The first two missions that we see using the shuttle in this mode are the pointed versions of HEAO, HEAO C and D and the large space telescope. In both cases we have an established project management center, the Marshall Space Flight Center; we are working with appropriate advisory groups; and, while there is a great deal of work to be done and a great many tradeoffs and decisions to be made, I think we have the basic mechanism laid out to bring these systems into being.

Therefore, we are not asking this workshop to consider this mode of operation of the shuttle. However, in your considerations for the use of the sortie mode, you should certainly assume that there will be long-lived observatories operating in the late 70's and early 80's along with the sortie mode.

Let me now turn to the third mode which is the subject of this workshop, the so-called sortie mode or "research mode" as I am inclined to think of it. It is the mode which I believe will have the greatest effect on the way we conduct research in space.

By the sortie mode, of course, we mean the capability the shuttle has of carrying substantial amounts of equipment into orbit together with people to use that equipment in space for up to 30 days or smaller amounts of equipment and up to seven, as they're called, payload specialists.

Furthermore, these payload specialists can be scientists, engineers, technicians, doctors or what-have-you.

In addition, these people need not be astronauts or even scientist-astronauts requiring several years of training. Rather, they can be healthy scientists or engineers who will have had a training and conditioning course of a few months.

The basic definition of the sortie mode is limited to equipment which stays with the shuttle for seven to 30 days. However, we intuitively feel that to fully exploit the potential of the sortie mode we will need the capability to extend booms, to deploy experiments in space or occulting devices in space near the laboratory.

Therefore, as I said before, for the purposes of this week's workshop, we have defined the sortie mode as including experiments or equipment to be left in space but recovered within six months.

Figure 1-8 is an artist's conception of one way a shuttle sortie might look. I like it because it shows both a laboratory with men in it performing experiments

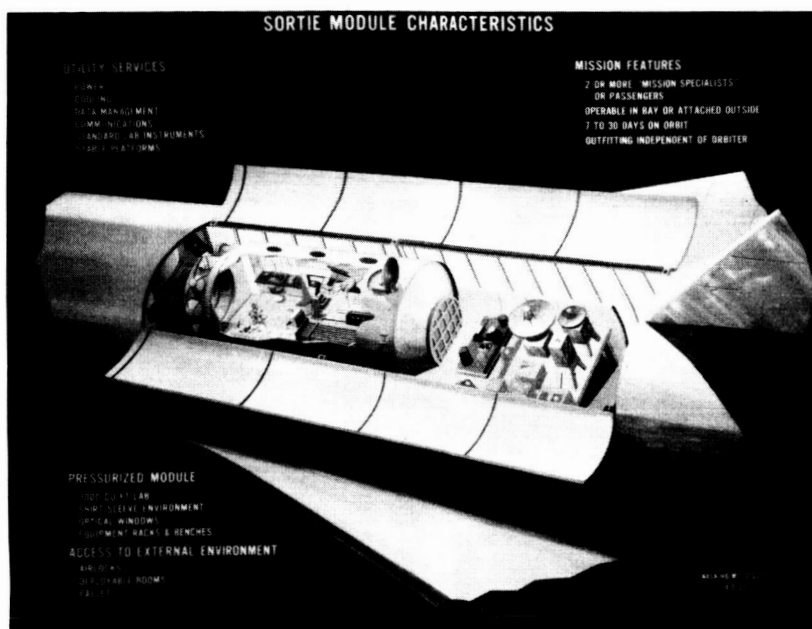


Figure 1-8

and a pallet to support automated equipment directly exposed to space. The sortie mode gives us for the first time the capability of putting man where he can be most useful, either on the ground operating his equipment remotely or in space with his equipment.

Figure 1-8 also illustrates one of the major questions about the way we will use the sortie mode. Should we drive the design of the shuttle and the sortie module toward more payload specialists beyond the nominal two, or toward a minimum of payload specialists and a longer stay time in orbit beyond the nominal seven days?

In talking to scientists about the use of the sortie mode, I find a tendency for them to be polarized into two camps. One camp seems to be populated primarily by people who up to this time have done most of their research in the laboratory. They argue very strongly that the principal value of the sortie mode will be its capability to carry scientists or technicians and laboratory-like equipment into space so that you could do research in space more as you do it on the ground without having to generate a lot of documentation, design a complex experiment and conduct an elaborate calibration, quality control, and testing program.

The other camp is populated primarily by those who have spent a substantial part of their career doing research in space. They feel that the primary function of the sortie mode is to carry automated equipment into space and that the

value of the sortie mode comes from its ability to provide low-cost transportation to space and its large volume and weight capacity which will mean that they will no longer have to carefully design and constrain the size and weight of their equipment as they do in our present spacecraft.

Now, obviously, the nature of the sortie module or modules, the cans, the laboratories or the pallets that we design will be strongly influenced by which of these groups is right or whether, as is most likely the case, there is merit to both their cases.

Figure 1-9 is a similar attempt to assess the impact of the sortie mode on our way of doing business.

<u>ACTIVITY</u>	<u>IMPACT</u>
SR&T	MAJOR CHANGE FROM GROUND-BASED TO SPACE SR&T
PAYLOAD	MAJOR CHANGE FROM INDIVIDUAL PAYLOADS TO RESEARCH PROGRAMS
ROLE OF SCIENTISTS	MAJOR CHANGE – BEST ROLE TO BE DETERMINED
TIME FROM CONCEPT TO PUBLICATION	CAN AND SHOULD BE MUCH SHORTER
SPACECRAFT DESIGN & DEVELOPMENT	MAJOR CHANGE FROM COMPLEX, COSTLY SPACE FLIGHT HARDWARE TO SIMPLER LABORATORY LIKE EQUIPMENT
SPACECRAFT OPERATION	MAJOR CHANGE – STILL TO BE DEFINED
REPAIR, REFURBISHMENT & RETRIEVAL	WILL BECOME A ROUTINE PART OF SPACE RESEARCH

Figure 1-9. Impact of Mode III Sortie Mode

As you can see, it will affect every aspect of our present way of doing business. We really will not understand the full impact until we have used for four or five years just as it was difficult for the first few years of NASA to assess the full impact of satellites on the traditional methods of doing scientific research.

Certainly, the availability of the sortie mode will have a major impact on our SR&T activity. For one thing, some of the work that we have traditionally done in our SR&T activity in the laboratory or with balloons, aircraft, and sounding rockets is likely to be done on sortie missions themselves.

We will very likely change our thinking about payload selections away from the concept of an individual spacecraft such as an OSO to the concept of several research groups conducting solar physics research using the sortie mode in the same way that we are currently using the 990, the Lear jet and plan to use the C-141 to support an infrared astronomy program.

Clearly, there will be major changes in spacecraft design and operation if, indeed, we actually continue to think of spacecraft in connection with the sortie mode. The time between concept and publication should be considerably shorter, both because it should take considerably less time to prepare an experiment for flight in a sortie laboratory and because of the shorter lead time for launches and more frequent flight opportunities.

The important thing is to approach the use of the sortie mode with as few preconceived or traditional ideas as possible and with all the creative innovative ideas you have. The sortie mode should permit major changes in our way of doing business.

We are prepared to change any or all of our present policies and procedures for SR&T, experimenter selection, the role of scientists, or even the amount of documentation where such changes will help exploit the use of the sortie mode for scientific research.

As a general agency-wide policy, we intend to approach the development of the sortie mode in terms of what changes we have to make in the airborne mode of doing business to adapt it to the sortie mode, rather than in terms of how we can simplify existing automated or manned procedures for the sortie mode.

To be very explicit, any formal documentation, any complex or costly testing program for the sortie mode, which is not used in the airborne program, should and will have to be justified for the sortie mode.

We should start immediately, in fact, at this workshop to develop the new ideas, policies and concepts that will take full advantage of the shuttle capabilities and potential.

I have wanted to discuss to this degree our present plans for the use of the shuttle so that all of you could understand what we mean by the sortie mode and what we are looking for from this workshop.

I will now take up the objectives of this workshop, why are we having it, what we hope to accomplish, what questions we want you to answer.

Figure 1-10 shows the primary objectives for the workshop. The first and probably the most important objective is to tell you, the potential users, what the sortie mode can do for you.

1. INFORM POTENTIAL NASA USERS OF THE CHARACTERISTICS OF THE SORTIE MODE AND OF THE CRITICAL INFORMATION NEEDED FOR THE DESIGN OF THE SORTIE SYSTEM.
2. REVIEW THE OBJECTIVES FOR SPACE RESEARCH, DEVELOPMENT AND APPLICATION FOR THE 1980'S AND DETERMINE THE PROPER ROLE FOR THE SORTIE MODE IN THEIR ACCOMPLISHMENT.
3. REVIEW THE POTENTIAL OF THE SORTIE MODE TO SEE IF THERE ARE NEW OBJECTIVES WE CAN ESTABLISH.
4. DETERMINE AS FAR AS POSSIBLE THE OPTIMUM CONFIGURATION OF THE SORTIE MODE FOR YOUR DISCIPLINE.
5. IDENTIFY, WHERE POSSIBLE, SPECIFIC SORTIE MISSIONS AND THEIR REQUIREMENTS.
6. IDENTIFY ANY SR&T AND ADVANCED STUDY ACTIVITY WHICH IS NEEDED TO HELP PREPARE FOR THE USE OF SORTIE MODE.
7. IDENTIFY, WHERE POSSIBLE, THE POLICIES AND PROCEDURES WHICH MUST BE CHANGED OR INSTITUTED SO THAT WE CAN FULLY EXPLOIT THE POTENTIAL OF THE SORTIE MODE AND REDUCE THE COST OF RESEARCH IN SPACE.
8. DETERMINE THE NEXT SERIES OF STEPS TO INVOLVE POTENTIAL NON-NASA USERS IN THE PLANNING FOR THE SORTIE MODE.

Figure 1-10. Objectives of Workshop

There is also information, as George Low indicated, that is needed by the shuttle program to help with the design of the sortie laboratory which can only come from you people who will be conducting research and development in space in the 1980's.

The second task for the discipline groups is to review the objectives for space research for the 1980's and determine which of these can be best accomplished through the sortie mode. These can draw heavily on existing statements of objectives such as, in the case of astronomy, the Astronomy Missions Board reports and the Greenstein Report.

However, we also want you to give some thought to the potential that the sortie mode offers to see if there are new or redefined objectives that we in the agency can establish by virtue of the capability of the shuttle.

We also want you to recommend what seems to be the best configuration of the sortie mode for your discipline. By that, we want to know whether the R&D, the research and development work you will be doing is best served by a



laboratory configuration with people performing experiments, doing on-board analysis of the data, modifying the apparatus during a mission; or, are they better served by a pallet like configuration which essentially supports automated instruments; or, is the work such that you will need both or something entirely different that we haven't talked about at all?

What are you likely to want in the way of ports, scan platforms, power, telemetry and data processing equipment? Are you likely to want to place equipment outside the sortie or leave it in orbit for several months and then retrieve it?

Next, we would like to have you identify, where possible, examples of specific sortie missions and their requirements.

We would also like you to identify any SR&T or study work you feel is urgently needed to prepare for the use of the sortie mode or to help define the proper configuration.

We would also like you to identify policies and procedures which must be changed or instituted if we are to fully exploit the potential of the sortie mode and reduce the cost and time of doing work in space. We expect new roles for scientists and new institutional arrangements.

We realize that we are probably asking for more than you can accomplish in these five days, but you should be able to make a good start. We intend to continue with this workshop. We also want to begin to involve the academic scientists, the international scientists, the entire external scientific community in a systematic way in the planning for the use of the shuttle.

Therefore, since we will need to continue the work you are starting and bring in non-NASA scientists and engineers, we want your advice and recommendations on the best way to do that for your discipline.

As I said, we have a proposed course of action for you to consider which we feel is reasonable from a standpoint of shuttle, schedule, workload and availability of technical information.

Figure 1-11 shows some of the things we plan to do following this workshop.

The first thing we will do will be to review the results of this workshop with our European colleagues and arrange for their participation in the planning of the sortie mode.

1.	REVIEW THE RESULTS OF THIS WORKSHOP WITH EUROPEAN SPACE COUNCIL AND ARRANGE FOR THEIR PARTICIPATION IN FUTURE WORKSHOPS	AUGUST 7-11, 1972
2.	REVIEW RESULTS WITH SPACE SCIENCE BOARD AND ARRANGE FOR NATIONAL ACADEMY OF SCIENCE PARTICIPATION IN SHUTTLE PLANNING	AUGUST 30-31, 1972
3.	PROCEED WITH DISCIPLINE WORKSHOPS INVOLVING EXTERNAL SCIENTISTS	SEPTEMBER 1972 - JANUARY 1973
4.	DISTRIBUTION OF DISCIPLINE REPORTS TO SUMMER STUDY PARTICIPANTS	MARCH 1973
5.	NATIONAL ACADEMY SUMMER STUDY TO REVIEW SHUTTLE PAYLOAD PLANNING	JULY 1973

Figure 1-11. Future Plans and Actions

As most of you know, there is a possibility that a European consortium will build some of the sortie laboratories; therefore, it is extremely important that they participate very closely with us, and we with them, as we develop our concepts of the best way to use the sortie mode.

We have already had some preliminary discussions with the Space Science Board as to their participation in the planning of the use of the shuttle. We plan to review the results of the workshop with them at their next meeting on the 30th and 31st of August. At that time we will also review our plans to involve academic scientists with the intention of requesting the National Academy to review, comment, and help us further develop our plans for the use of the shuttle and to consider additional uses for it at a summer study to be conducted in July of 1973.

We plan to proceed with additional discipline workshops involving academic scientists just as soon as possible. We expect to begin those in September and expect that there may have to be several meetings of each workshop extending at least through January.

While we are planning to conduct this activity through discipline workshops, we very likely will have an initial meeting of at least all the scientific disciplines where those who have not attended this workshop could be briefed on the characteristics of the shuttle.

Such a general briefing may not be necessary if we prepare a good document from this workshop which will provide to a prospective user the pertinent characteristics of the shuttle and the sortie mode so that he can participate intelligently in the workshops.

While I have indicated that the workshops we will have throughout the fall will be conducted on a discipline basis, obviously we will establish the necessary steering groups and procedures so that the results of the workshops are reviewed and integrated into the total planning of the shuttle and as new ideas are developed or as specific configurations of the sortie module appear to be more attractive than others, we will see that that information is promptly given to each discipline workshop.

While we have limited the scope of this workshop to the sortie mode because we feel that is where the most work needs to be done, these later discipline workshops will consider all three modes of the shuttle.

Finally, let me emphasize that I am aware that we have laid out a considerable amount of work. I think that what we are setting in motion here is important and worth that work. This is not an academic exercise. This is not just another exercise to produce another blue or green book of "for instance" experiments to be fed into more industry studies.

This, as I said earlier, is the first step in a long process that will take us from where we are now, through the development of specific payloads, specific research programs, specific equipment and systems so that by the late 1970's and early 1980's we will have the people, experiments, and the necessary hardware to exploit the full potential of the shuttle when it becomes operational.

This is the same process that we went through in 1959 and the early 1960's when we developed the concepts of OGO, IMP and OAO and the policies and procedures by which we put them to use by scientists around the world.

It is the same kind of process that we went through starting in 1964 which led to the scientific results from Apollo and to the initiation of HEAO, Viking and the rest of the present planetary program.

I cannot speak for the other users of the shuttle but for myself and for the Office of Space Science I can say that with this workshop we are beginning the process that will lead to the people, the policies, procedures and hardware that we will use to conduct scientific research in space in the decade of the 1980's.

So if you are interested in participating in such activity or if you are here representing younger people who will be participating, then you will find your support, recommendations and contributions very rewarding.

The work you do here will help assure that the program that evolves and the hardware that is built is most responsive to the interest of your discipline.

Thank you for your interest and contribution to this workshop.

PROGRAM OVERVIEW  
SHUTTLE SORTIE WORKSHOP  
JULY 31, 1972

Charles W. Mathews  
Associate Administrator  
Office of Applications, NASA Headquarters

I stand before you as the living example of the melding of the manned and unmanned programs. I guess some of you know what I mean by that.

I am to talk to you rather informally about the shuttle — the sortie module — and a thing called applications. I am going to make a statement that I have heard many times and that I believe: The shuttle needs applications. I also want to say that the converse is probably even more true, that applications needs the shuttle. I would like to try to develop those two points.

I believe, of course, that the applications needing the shuttle is dominantly related to easy access to space. There is no question in my mind that there are many important applications of our ability to move in and operate in and then move back out of space regime. We have seen so many of these already, and they are just the beginning. Most of them deal with the idea of looking down at Mother Earth. The timing for those looks is very important right now in terms of people's feelings about Mother Earth and limitations of its resources, as well as our concerns about the closed nature of its environment.

We are therefore moving into applications regimes in a very timely fashion. But as we work this problem, we find it very trying and tedious and difficult to operate in space, and so we haven't been developing these applications very rapidly. This is where the shuttle will ultimately come in — to move us easily or much more easily into space and to make it more economical.

I remember in the Mercury program, we had difficulties in getting people down to the Cape often as they should, early in the program. Therefore, we developed a shuttle, a Martin 404 which wasn't even too much of an airplane in those days. Nevertheless, it made a tremendous difference, because people were not determining just — you know, should I really go down to the Cape this time, it is a lot of trouble, I have to go out to the airport and so forth.

We moved right out of Langley Field where we were stationed at the time. We found it very easy to move back and forth, and I think this had a lot to do with the development and success of the Mercury program, and ultimately the Manned program.

On the other hand, I think the shuttle does need applications because, I believe there is a tendency for people to expect a real, tangible benefit to come out of things in order to have that activity established at a reasonable level of activity.

For example, if the activities are purely of a scientific nature — and I am not doing anything to rate scientific endeavors because I kind of feel, although most people wouldn't call me that, I kind of feel I am a scientist too, you see. But I think that is a level of activity that will reach a certain level and it will take these direct benefits before the level goes above this.

So I think applications are just very important. Now, what is an application? (For the definition of applications, see Figure 1-12.) Applications are really

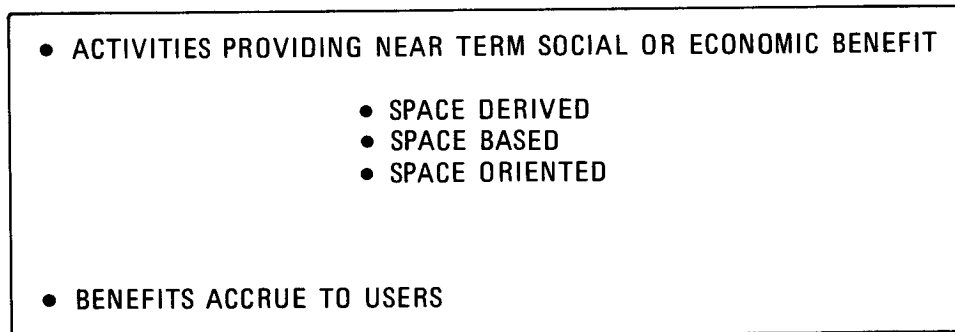


Figure 1-12. Applications

activities providing near-term, social and economic benefit. Now, the applications that we are interested in are related to space in some way, because this is the charter of the agency. They don't necessarily have to all end up flying something in space; that is, the space-based activities. They can be things that happen here on earth, because of some knowledge or experience we have had from space flight or operating in space, or, they can begin on the ground with the idea that they will probably some day thread their way into space.

We have all these things going on. The main point, I believe, is the idea of near-term social and economic benefit. For instance, a jet transport in itself is not really an application. I guess George Low somewhat alluded to this. The fact that a jet transport can fly at a certain speed or attain a certain altitude, etc., is not, in itself, an application. The fact that it moves people about (moves businessmen about in a way that they have come to judge it as a means to produce economy in their operations) brings in the economic benefit. The

fact that it moves people to Europe, Hawaii, etc., where they can get their R&R and come back refreshed is undoubtedly a social benefit. In that sense, the jet transport is indeed an application, and people say, "It is here we are going to use it, we want to use it," and so forth.

That brings me to the point of benefits accrue to users. They don't accrue to NASA or to the aerospace industry or anything else except in an indirect sense. They accrue because people say, "I am benefitting from that activity," some segment of the public, some segment of a user organization that probably supports the public.

Now, what do we intend to do in applications? Figure 1-13 lists our general objectives. We are not shy about it. We want to establish useful applications of space and space knowhow. We are not saying we are going to try to force-feed this thing. We are just saying that we know that applications exist, that they need to be developed rapidly and efficiently, and that we are going to do this as a number one priority by developing these user relationships.


- 
- ESTABLISH USEFUL APPLICATIONS OF SPACE AND SPACE KNOW-HOW
    - DEVELOP USER RELATIONSHIPS
    - DEVELOP REQUISITE TECHNOLOGY
    - CONDUCT APPROPRIATE GROUND, AIRBORNE AND SPACE FLIGHT INVESTIGATIONS
  - PROVIDE SUPPORT TO OPERATIONAL SYSTEMS
  - CONTRIBUTE TO NATIONAL SPACE EXPERTISE

Figure 1-13. Applications Program Objectives

Again, not the idea, that we have the best thing in the world for you, why aren't you interested in it? But, we understand that you have a problem or a desire to do investigative work, or something like that, and we think our capability, as related to the sortie module or something else, is very closely related to help in the solution of your problems.

Developing the sortie module, then, comes under the category of developing instruments requisite technology. NASA is very good at that. I don't need to say anything more about it.

The third thing, though, is that NASA intends to continue to conduct appropriate ground, airborne, and spaceflight investigations; that is, the shuttle. We now use Delta and a few other launch vehicles, but in the decade of the 80's, we will use the shuttle and, hopefully, quite easily. We will provide various support services to operational systems. We now launch satellites for COMSAT, the Weather Service, and so forth. This type of support for operational systems will continue in the shuttle area.

We will also have some new features. If things don't work just right, we can consider going up, getting them, and bringing them back or repairing them in place, whatever is more effective. This service will be entirely new for the operational systems, and will probably allow them to take on a slightly different direction. This is something you people should think about. In any case, we expect these applications to contribute to national space expertise and the general wellbeing of the nation.

The shuttle will support instrumented satellites, as well as manned programs (Figure 1-14). As a matter of fact, I think it is going to be pretty important to get off this kick of manned and unmanned programs. I will talk a little more about this in a minute.

However, the shuttle will provide a service. The Office of Manned Space Flight will provide services to the Office of Applications and the Office of Space Science, as well as to their own disciplinary-oriented activities such as the life sciences organization in terms of being able to carry the types of satellites — unmanned satellites, automated satellites — up, including 1980 versions. They will be able to conduct activities associated with earth orbital operations that are typical of what has been conducted in the past Manned Space Flight Program. I wouldn't say that they were unimportant. In doing this, we will not only be doing that job for NASA, but other agencies will become increasingly involved.

I think, of course, that the user-oriented organizations, the Office of Space Science, and the Office of Applications will be the primary interface with user organizations on uses. However, the shuttle people will need to interface with other organizations on how the shuttle is really applied to their particular activity, making sure that it is compatible, and that the payload designs and so forth will ultimately integrate well and effectively and economically into the shuttle concept.



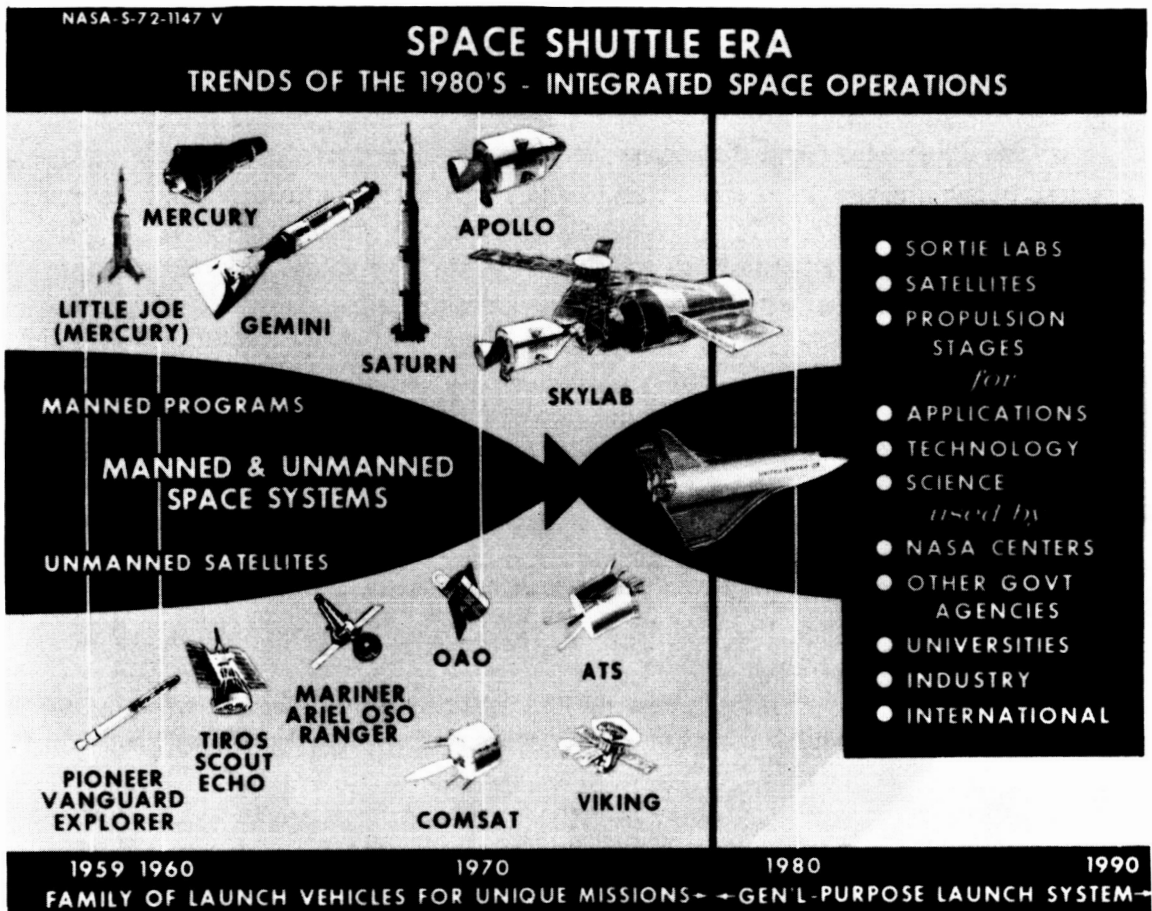


Figure 1-14

Commercial, Department of Defense, and international activities and they will occur in the sciences, the applications disciplines, and perhaps some others, and laboratories and observatories will be involved. The sortie module is one type of laboratory and also possibly one type of an observatory.

As I mentioned before, the big feature of the shuttle, in my mind, is the idea of routine operations. In other words, the two big things about the shuttle are the ones that are on the upper right-hand corner and the lower left-hand corner of Figure 1-15. I think they will allow us to be much more flexible in our choice of hardware. We won't have to shake, rattle and roll payloads, particularly in something like the sortie mode, because we don't see them again once they are launched or we are not able to get our hands on them once they are launched. I do think that the sortie module should behave very much more like a laboratory here on the ground in terms of equipment and the type of equipment it has on it, the general cost of that equipment, etc.

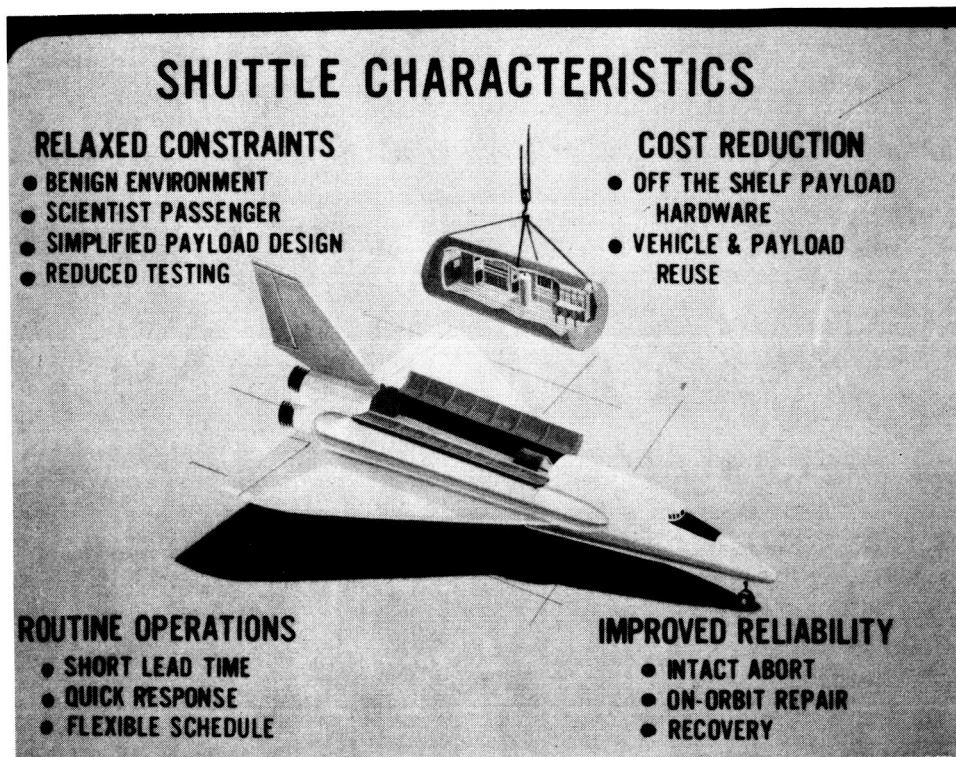


Figure 1-15

The routine operations of achieving short lead time, quick response, and flexible schedules are the things that will make the shuttle important to the applications program. As people get ideas, they will want to be able to try them out. Many times these ideas can't be tested or investigated adequately without actually being in the space environment, including observational activities as well as things that involve weightless activity. I would have to say that things that we now fly are often brought much too close to the operational stage before we fly them because they are so expensive, etc., and then we find they are not exactly what we want.

For example, we have flown many instruments in the Nimbus program — more than I think we would have to if we had the shuttle sortie mode. I am not criticizing the Nimbus program because, under the present conditions, that was the way to do it. But I think we can do a screening type of activity, get early leads and say, that is not quite the way I wanted it, but boy it gave me the idea, I better just go off about 10 degrees from the way I am going here, and then I will have it. You know, that kind of thing.

In addition, there are other features of the benign environment that allows scientist passengers, and can produce impacts on the design itself in terms of expanded volumetric capabilities and the ability to utilize the protective environment inside the payload bay of the shuttle. We should get improved reliability on the basis of being able to go up and repair, or bring things back.

The applications program will probably use the shuttle in all the ways shown in Figure 1-16. In delivery and retrieval of payloads, the communications satellites, the meteorological satellites, earth resources satellites, etc., will end up being in that category and I think, in the operational systems, they will probably be automated satellites.

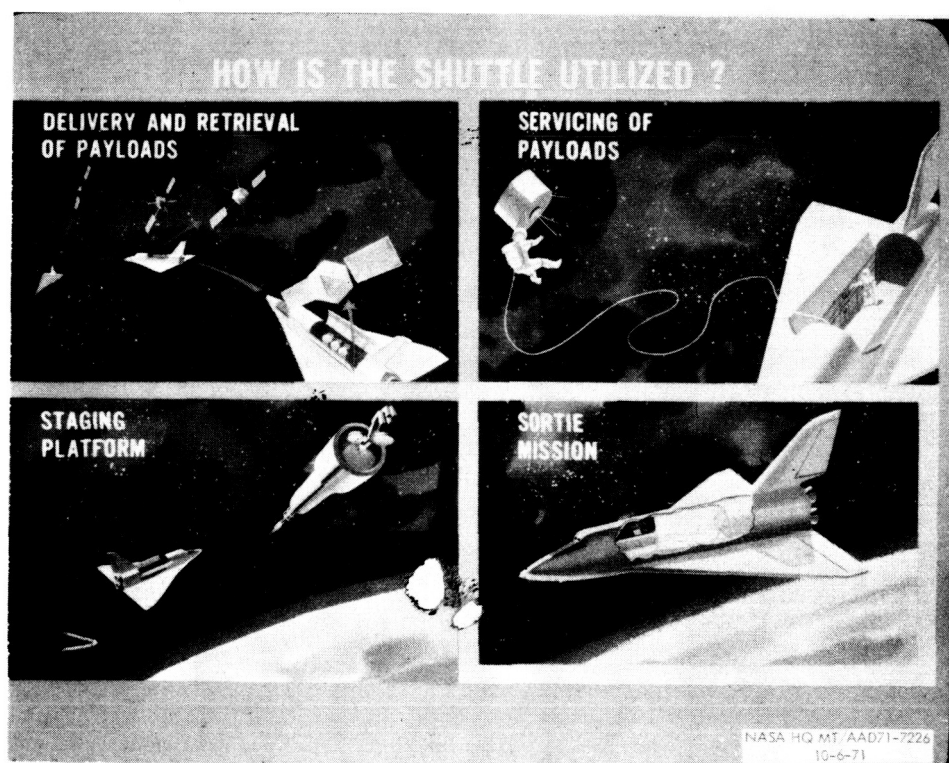


Figure 1-16

The large ones will undoubtedly involve considerations of servicing or retrieval and repair.

Another very important aspect to the applications program is the staging platform for a third-stage launch up to synchronous orbit because of the tremendous amount of applications traffic. It is a good place to look at the world, it is a

good place to flow the communications from, etc. I think that presents a problem that you people need to consider as a part of the workshop and I will talk about that in just a minute.

I am personally very interested in this sortie mission. It is a capability that we really have not had in any way, shape, or form in space flight. As people have said, we have had it on the 990.

Figure 1-17 shows the form of the shuttle sortie mode that is most attractive to me; that is, a fairly simple, not too neat lashup of equipment. I think that is typical of the ground-base laboratory. They are not neat. If they are neat, they are not being used properly. So, I think this is the way to do it.



Figure 1-17

There are really two modes. One is the sort of 990 mode, which involves activities in simplistic and unsophisticated screening endeavors, where probably the most important thoughts come out. Another mode, which I will call the facilities mode, has to be treated very carefully. This mode will have some very tremendous earth resources laboratory concept which will probably, if we

don't watch out, be obsolete before we get it up there and will probably have some of the same features of, gee, that instrument isn't quite the way we wanted it. I wish it was a little something different. I don't rule it out. I think you have to be very careful about your approach to that particular activity, and that you can get right back into some of the problems we have right now in terms of automated satellites and manned space stations.

Figure 1-18 illustrates a number of significant features. One is that it doesn't illustrate a strongly, highly specialized facility. It says, "I am going to have a laboratory just like here on the ground, I am going to supply electrical power, I am going to supply an environment in there, I am going to supply some normal services of data management, communications, standard lab instruments, etc." I think that is great. I think that is the kind of thing you want to put up in that lab. It has its pressurized module with some men in it. It is inconceivable to me that you would have a laboratory here on the ground without some men hovering around. They might be just technicians. Maybe you scientists and so forth wouldn't want to be in that lab, but I think you would at least have some technicians in there. The only reason they wouldn't be in there would be if the situation was really too dangerous for them to be in there. I suspect that in

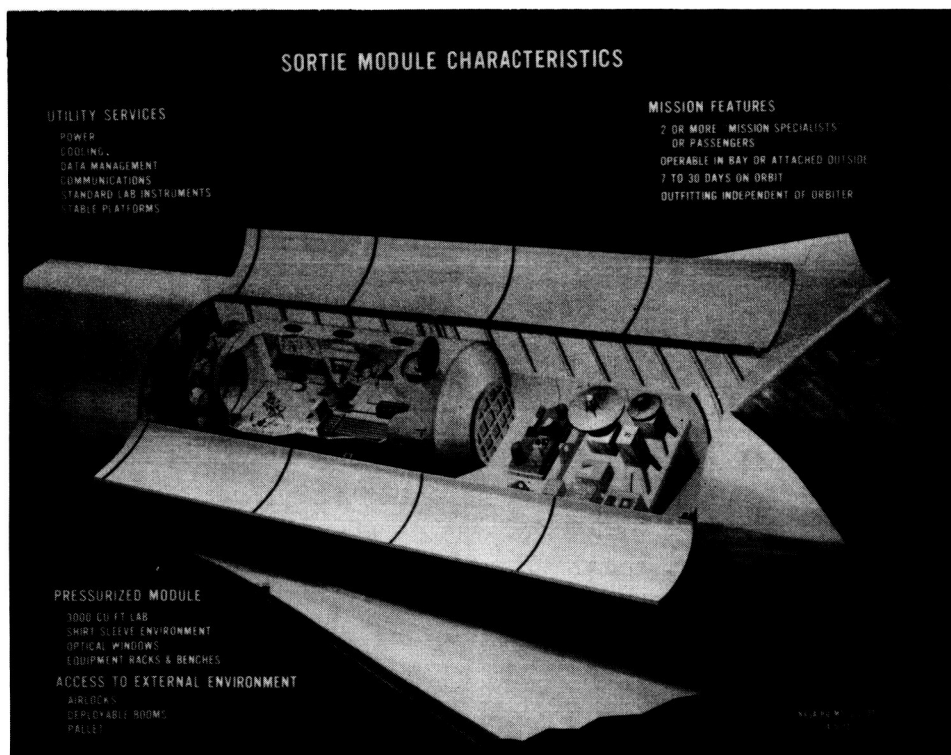


Figure 1-18

certain types of labs run by the AEC, that may very well be the case. And I have to admit, there are some cases up in space that might be a little like that, because I have run some EVA operations and know a little bit about that.

The main point, I believe, is that this business of unmanned and manned space flight is kind of a figment of somebody's imagination in terms of a direct comparison of doing the same things. They are really an apples and oranges type of activity. You don't put men in places where it is not safe to put them, and there are operational limitations on the fact that men are present. On the other hand, you don't do much innovating without man being present. You don't absorb the breadth of information without men being present either on the ground or up in space. I am not saying which way.

I think the lunar geology is typical. You could do a certain class of lunar geology in an automated mode. I don't think you would do the class of lunar geology that is associated with the Apollo mission in the automated mode. Therefore, I am pleased to see that this pressurized module allows for a shirt-sleeve environment. I am also pleased to see that there are some things mounted on the outside. I am not even sure I want the guys to go out and monkey with that, although they could do that with EVA. I think, in the main, that you probably will bring the sortie module back down on the ground before you monkey with that equipment outside there.

So the men will be doing the kinds of things they should be doing. That is another point. A manned system is always automated in this day and age. It is usually rather heavily automated, and you don't have them doing things that aren't very worthwhile just because he is up there. That is the other side of the story.

So he is up there to do interpretive work, to do an earth resources — characterize the scene. It is hard for instruments to determine whether something is hazy down there or it is bright. That is a little hard to do. But a man's rather broad perspective of our aspect of visual sensing allows him to characterize a scene. I think that is a good thing for him to do.

Meanwhile, some very precise sensors may be operating on the outside, not encumbered by windows and not even operating necessarily in the visual regime as on ERTS which has three bands that the man can't use at all because he can't sense them, and, of course, other things that involve microwave electronics. He really has got no capability — at least to my knowledge — in the microwave region.



I think John Naugle and I think pretty much alike on this business from what I have heard him say. We want people aboard this thing under conditions where they are really contributing to the activity. I feel strongly that they will. But we don't want them operating in a way that constrains the operation because of safety considerations or violates the safety of our present manned operations.

I think the two main applications of the shuttle sortie mission (Figure 1-19) involve observation of the earth and flow of communications above the earth. I think these are very important. Although there will be other important applications, I expect those to be mainstream activities for sometime to come. I say that because they can do things that really can be done nowhere else and the need is already expressed by the humans of the world to get that kind of information. There are many aspects we don't know about. We don't know all our capabilities to sense. We don't know all about our capabilities to gather the information and bring it to centralized locations. We don't know all about our ability to interpret. We certainly don't know all our ability about handling management decisions based on the information that we get out of that. We are in a very preliminary stage here. Nevertheless, we can say it is extremely



Figure 1-19

important. I make this point because a lot of people say we haven't come up with any new applications recently.

I don't necessarily think it is of absolute importance always to come up with new applications. The airplane is a transportation system. It has a few other incidental applications like crop dusting, but it is basically a transportation system. It is a very multi-faceted thing and, as more capabilities develop, more uses of transportation exist.

I think the same is true in earth observations. We have many, many years of work to do in that area. Important things will be done very soon with ERTS information in areas such as land use. But many of the more sophisticated uses probably will be researched in the shuttle mode.

The same is true with communications. I think we started with rather rudimentary communications systems. Already we have strongly impacted the international communications, particularly across the Atlantic and across the Pacific. We are now just getting into the domestic field. That is of unknown potential, but practically explosive, I think, in terms of what is going to happen once it comes into being. And probably, some day, we will not be flying these airplanes on business to the degree that we are flying today, because we will sit home and use our wide band communications for the purpose.

However, in these two areas, the shuttle sortie operations has got, I think, a little different character in each case.

In earth observations, I really feel that the strong use of the sortie mode is really in the screening process, in looking at new instruments, looking at new sensing techniques, in providing a fair amount of information on rather diverse conditions, even disaster conditions where we may deploy the shuttle just to photograph large-scale disasters, for example.

So there are two facets. One is in the instrument development in the systems testing and verification that the instruments will do the job. The other is in doing the R&D type observations.

I think, as I said before, ultimately I believe the earth observations operational systems will probably, because of the requirements that they operate for very long times, and in a repetitive fashion, will operate in an automated mode, serviced — launched and serviced by the shuttle.

In communications the situation is a little different I think, in that the only aspect of the space environment that is really dominantly important, is the fact that you have got line of sight over such a large global area.



You usually know pretty much how to design the equipment, or know already. The main problems relate to the occupation of space with large amounts of communications gear covering many areas of the frequency spectrum that will be allocated to it and actually producing a tremendous amount of interference.

So we see the shuttle as a communications laboratory, dealing with interference problems. Probably even operationally dealing with interference problems.

Undoubtedly there will be other things involving propagation experiments. I think I probably gave that a little short shrift in my previous comments. There are still things to be known about propagation and so forth.

Space processing, I don't think will really be possible to develop to any major degree without the shuttle sortie mode. I think it is something that is just a very much of a natural to this mode and I think people working in that area really ought to concentrate hard on the shuttle sortie activity.

Technology applications are applications involved here on the ground. I think they tend to be indirect effects. For example, the idea of modular integrated housing systems which stop heating and cooling at the same time, and recover water and minimize solid waste are things we are working on, and they come out of the fact that we attempted this in building space equipment.

So I think the attempts to build the shuttle, the attempts to build a sortie module, and the follow-ons to the sortie modules and the follow-ons to the shuttle, certainly will continue to have those kind of applications, either in informational management systems, in environmental systems and so forth.

Geodesy earth and ocean physics applications, I think, probably are not as strong a candidate for the shuttle sortie mode as most of the others. Again, because even the research on them is so dominantly related to long-term space flights, stable orbits and so forth. But, as far as maybe the development of techniques, measurement techniques and so forth, this can be included.

I would like to have someone in this room prove to me how important the shuttle sortie mode is going to be to that area.

And then there are special, or future applications like the idea of generating solar power in space, like the ideas of carrying on certain very specialized types of communications activities, possibly military activities and so forth.

And I do not leave out the shuttle as a point-to-point transport on the surface of the earth. I think, my own personal opinion is that we will see that someday.

So I think those tend to be quite a ways out. They may be difficult to deal with in terms of this workshop, but I think some consideration needs to be given to them.

Figure 1-20 is a picture of a tug, or some sort of a third stage on a shuttle, going into synchronous orbit.



Figure 1-20

This is the one area that I don't think we have really quite figured out as to how we are going to embrace all the features of the shuttle in operations that take place at altitudes of 22,000 miles, say as compared to 500 miles.

I think it is a very important aspect. For instance in earth observations, I believe there will be requirements for development of instruments that work at this altitude. This synchronous meteorological satellite has a very sophisticated visible and infrared spin scanning radiometer that operates from this altitude.

There will be other instruments. There is a sounder instrument that is being talked about, to operate from this altitude. It is another operating regime that is out in the future someplace and has to be thought about.

Okay. Let's put on the final chart here.

<u>WITHIN NASA</u>	<u>AMONG THE USERS</u>
<ul style="list-style-type: none"><li>• ALL ORGANIZATION ELEMENTS CONTRIBUTE</li><li>• SPECIFIC PROGRAM RESPONSIBILITY TO CENTERS<ul style="list-style-type: none"><li>• LEAD CENTER CONCEPT</li><li>• FIRST LINE STATUS</li></ul></li><li>• EXPAND APPLICATIONS BASE</li><li>• CONDUCT DEMONSTRATION PROGRAMS</li></ul>	<ul style="list-style-type: none"><li>• EMPHASIZE INVOLVEMENT IN DEPTH</li><li>• PROVIDE IMAGE OF SERVICE AND SUPPORT</li><li>• UNDERSTAND USER PROBLEM AND MOTIVATIONS</li><li>• IDENTIFY AND SUPPORT SPOKESMEN</li><li>• ENCOURAGE INDUSTRIAL SUPPORT</li></ul>

Figure 1-21. Approaches to Applications Efforts

Figure 1-21 was not developed for the purpose of this meeting, but I think it had certain activities. I hope I gave you the idea that we are really not trying to just talk about sortie modules as sortie modules, and gee, this is a very nice thing, why don't you people use it.

We tried that with the space station two years ago at Ames and people were honestly very enthusiastic about the space station then. But they had not been able to be involved to the degree of depth that required that they knew just exactly how they would use it.

And I think it is very important when we talk about the shuttle modules, that we are bringing the users along and they know how they are going to use this thing and we can explain to the people that support us, how the users are going to use this thing.

Now part of that, of course, is that people kind of face up to applications efforts, and that all the organizations of NASA contribute. The ideas for these things come from the field, they don't come from Headquarters. So we are going to delegate responsibilities to the field.

As you know, we have established lead centers. We are going to establish more. Most of those lead centers have first-line status in the agency, and by doing that we are going to expand our applications base. And we will end up conducting demonstration programs and that is where the shuttle comes in.

Now, among the users, we do have to emphasize our involvement with them in depth from the word go. And we need to provide an image of service and support. That is, we want to have the sortie module designed in such a way that those users are convinced that, boy, they really had something to do about that, and it is something that is useful for their purpose, not for our purposes.

And therefore, we need to understand the user's problems and his motivations and we need to go out and identify and support spokesmen. That is, we need to have people that can talk for the users.

I think it is very important in this workshop, even here, to establish that kind of interface.

And, of course, I think we need to encourage industrial support. That is somewhat of an ancillary remark, but I do feel outside the aerospace industry, we do not have the best information flow between industry and ourselves.

Again, there are many industrial applications that could use the shuttle sortie mode, particularly in the space processing area.

So I think that fairly well covers my rather random thoughts on this matter. I think this meeting is very important, and I commend to you these thoughts and the thoughts of John, with the hope that maybe we have just given you a germ of an idea that you will now go off and develop.

Thank you very much.

SECTION 2

"SYNTHESIZED" PRESENTATION

OF THE

SPACE SHUTTLE

AT THE

SPACE SHUTTLE SORTIE WORKSHOP

JULY 31-AUGUST 4, 1972

**PART 2**

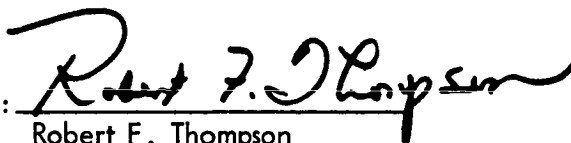
**SPACE SHUTTLE BASELINE ACCOMMODATIONS  
FOR PAYLOADS**

MSC-06900

SPACE SHUTTLE  
BASELINE ACCOMMODATIONS FOR PAYLOADS  
JUNE 27, 1972

PREPARED BY  
PAYLOAD ENGINEERING OFFICE  
FUTURE PROGRAMS DIVISION  
ENGINEERING AND DEVELOPMENT DIRECTORATE  
  
MANNED SPACECRAFT CENTER  
HOUSTON, TEXAS

Approved: \_\_\_\_\_



Robert F. Thompson  
Manager, Space Shuttle Program

"SYNTHESIZED" PRESENTATION OF THE SPACE SHUTTLE  
AT THE SPACE SHUTTLE SORTIE WORKSHOP  
JULY 31 — AUGUST 4, 1972

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## INTRODUCTION

The Space Shuttle Program material included in this document is presented in three parts.

Part 1. Space Shuttle Overview

Part 2. Space Shuttle Baseline Accommodations for Payloads

Part 3. Supplement

Part 1 is an overview of the Space Shuttle Program that briefly discusses the primary goal of the program to provide low-cost transportation to and from near earth orbit.

Part 2 is an official Space Shuttle Program document (MSC-06900) that provides information of particular interest and usefulness to potential Shuttle users. It is designed to be a primary reference document for preliminary payload planning and design studies. The document is updated periodically and any individual with a continuing need for information of this type should contact J. C. Heberlig, Code LP, NASA Manned Spacecraft Center, Houston, Texas 77058, for inclusion on the automatic distribution list.

Part 3 supplements the accommodation document with: (1) data of a more tentative nature that has not been incorporated in the document and (2) other shuttle-related information of interest to sortie users.

## PART 1

### SPACE SHUTTLE OVERVIEW

#### SPACE SHUTTLE ERA

The space shuttle era will begin approximately 20 years after the first U.S. venture into space, which was the launch of Explorer I on January 31, 1958. Unmanned satellites have probed the near and distant reaches of space, providing the basic scientific data for more comprehensive missions. Manned systems have evolved from a technological and operational base that has provided a capability for manned exploration of the lunar surface and for continuing operations of lunar scientific stations.

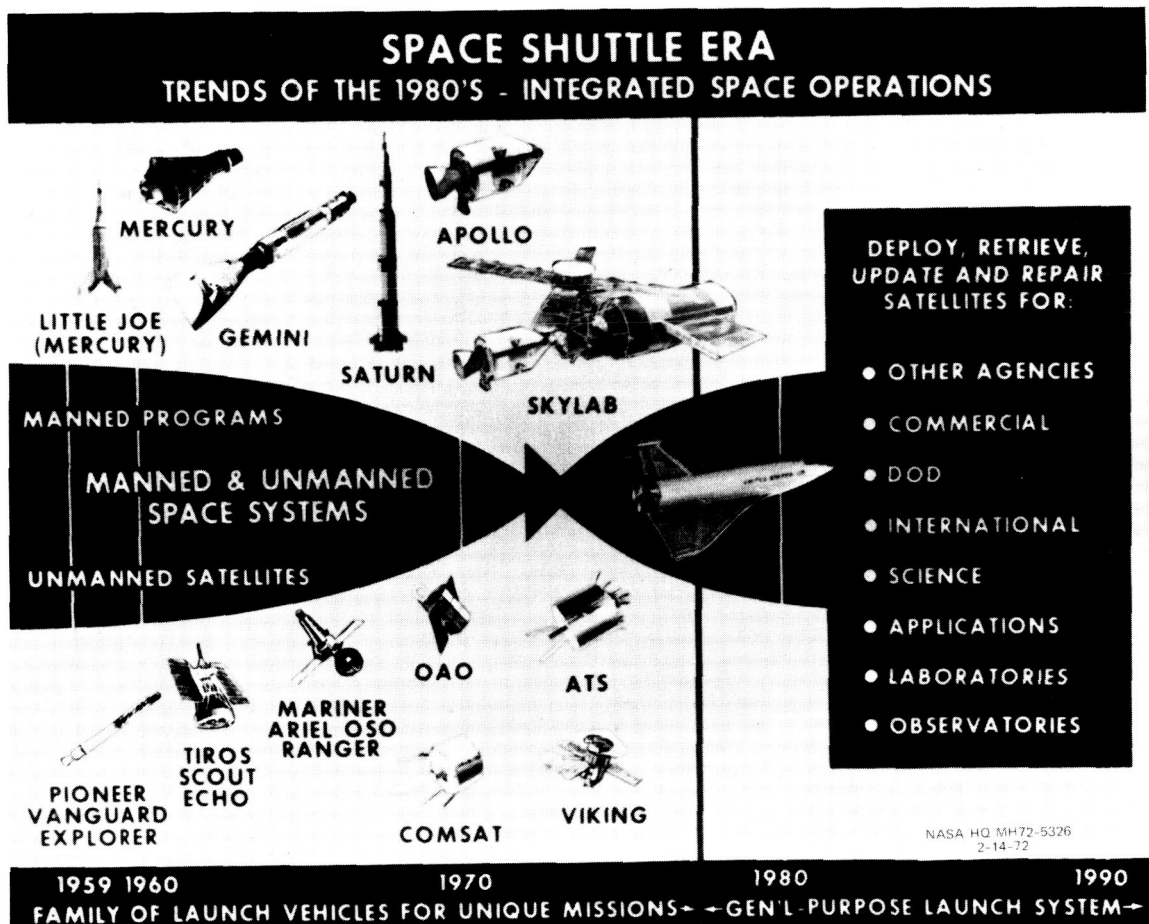


Figure 2-2

The primary goal for the Space Shuttle Program is to provide low-cost transportation to and from near earth orbit. The presentation that follows, together with the reference material, will provide current planning information and technical data from the NASA Centers and contractor studies. Results to date indicate that the Space Shuttle Program will provide for a variety of payload classes. Sortie labs with airlocks and mounting platforms (pallets) will provide general-purpose support capabilities to meet many needs. Free flying or automated satellites will be deployed and recovered from many types of orbits. Automated satellites with propulsive stages can be deployed from the space shuttle payload bay and placed into the desired trajectory.

This approach to space operations will yield broad areas of payload potential and a capability for conducting investigations of applications, technology, and science. Many participants representing diverse backgrounds and needs will work in these space operations. The continuing challenges will be to obtain and operate a low-cost transportation system with low-cost payload approaches. This savings will permit a greater amount of available research and development (R&D) funding to be applied to the sensors, instruments, and supporting hardware.

#### SPACE SHUTTLE MISSION PROFILE

The space shuttle mission begins with the installation of the mission payload into the payload bay. Normally, the payload will have been checked out and serviced before installation and will remain in a quiescent state except for flight safety items that require the caution and warning system.

After a few days on the launch pad, lift-off occurs, the two solid rocket motors are jettisoned after burnout and recovered for reuse by using a parachute system, and the large hydrogen and oxygen tank is jettisoned after it is used to place the space shuttle into a 50- by 100-nautical-mile orbit. The orbital maneuvering system is then used to obtain the desired orbit characteristics and any subsequent maneuvers that may be required.

The payload bay doors open to expose the orbiter radiators for the required amount of heat rejection. The crew is then ready to begin payload operations. A normal mission duration will be 7 days, with current growth estimates of as many as 30 days with the addition of consumables.

Entry is made into the atmosphere at a high angle of attack; at a low altitude, an aircraft horizontal flight attitude is assumed with energy management techniques to approach and execute an aircraft-type landing.

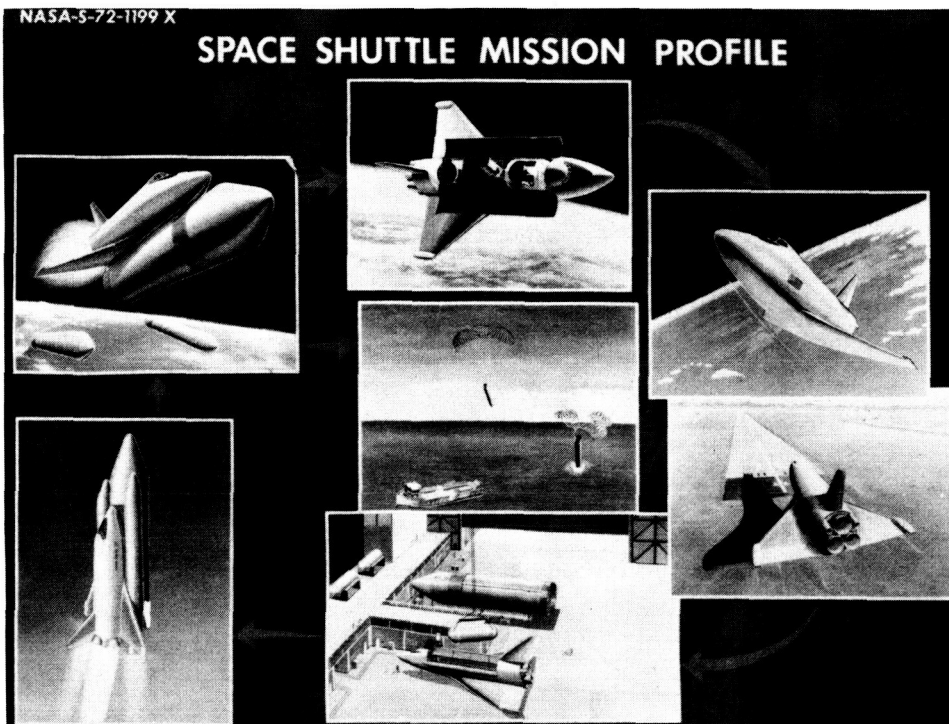


Figure 2-3

A 2-week turnaround on the ground is the goal for reuse of the space shuttle orbiter.

### SPACE SHUTTLE OPERATIONS

While the space shuttle is in orbit, many operations may occur. Sortie lab payloads or those payloads that require zero gravity and/or the vacuum of space can both be deployed. Payloads with one or more of the currently available propulsions stages and new ones now under study can also be deployed. It has been postulated that payloads and upper stages will be retrieved to capitalize on reuse. Many free flying or automated satellites may be placed in a desired orbit and later visited for service or repair. These are areas requiring joint activity by the payload community and the Space Shuttle Program.

Eventually, the space shuttle will carry passengers who make up the onboard space team to a space station and will carry modules that provide the facility requirements to and from the space station. Rescue and satellite recovery are inherent capabilities of the space shuttle quick response system.

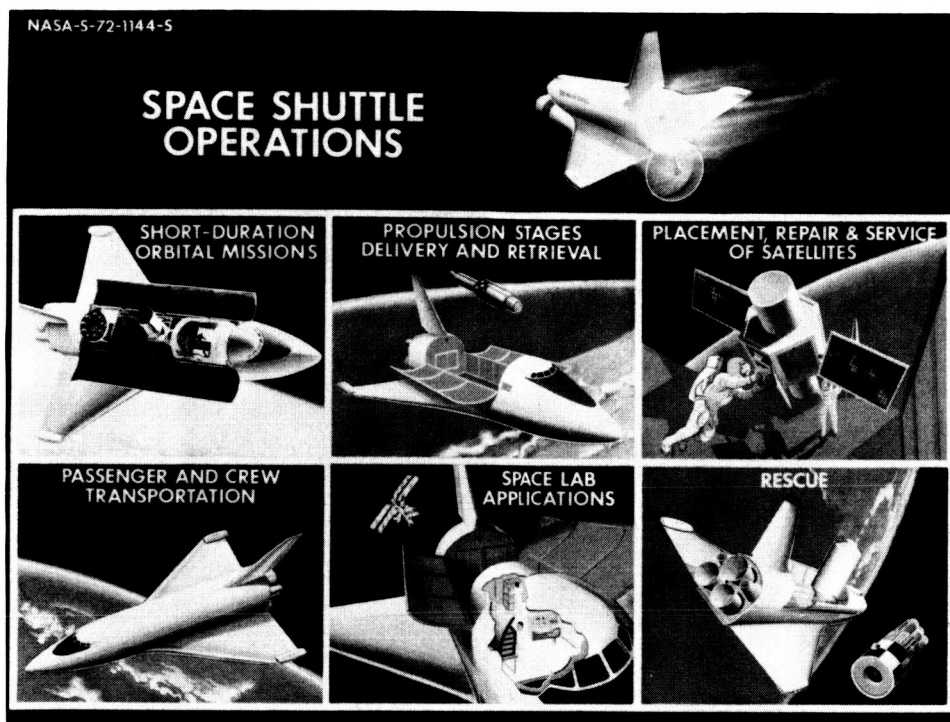


Figure 2-4

## SORTIE LAB

The sortie lab will consist of a combination of the standardized pressurized volumes, airlocks, and mounting platforms (pallets) to support the applications, technology, and science payloads from 7 to 30 days. The figure is typical of the concepts in preliminary definition by the Marshall Space Flight Center. The 14.7-psi (760 torr) shirt sleeve environment of the pressurized volume should make possible the use of much ground laboratory equipment with minimum modification. Instruments externally mounted on pallets can be controlled from inside the sortie lab or from the orbiter crew cabin if a full pallet is used in the payload bay. Space suit operations in the payload bay or around the space shuttle orbiter are practical when they are cost effective. Sortie lab operations will directly involve scientists, technicians, engineers, medical doctors, and others. Previously, these persons have trained other personnel to perform their inflight experimentation.



Figure 2-5

### FREE FLYING OR AUTOMATED SATELLITES

The wide operational capability of the space shuttle can make possible the placement and retrieval of many free flying or automated satellites. To date, limited studies indicate that existing space hardware can be used as well as newer systems currently being designed by several NASA Centers and/or the contractors. More than one satellite can be deployed or recovered for each mission, depending on the mission. Many times, smaller satellites of this payload class may be part of the mission payload, made up primarily of the sortie lab or a propulsion stage. Because of the almost total elimination of weight restraints for this payload class and the relaxation of confined packaging requirements, cost reductions (from complexity elimination) should be significant. The use of existing hardware, standardized equipment, retrieval, and reuse are areas where the payload community and the Space Shuttle Program have a need for continued dialogue.

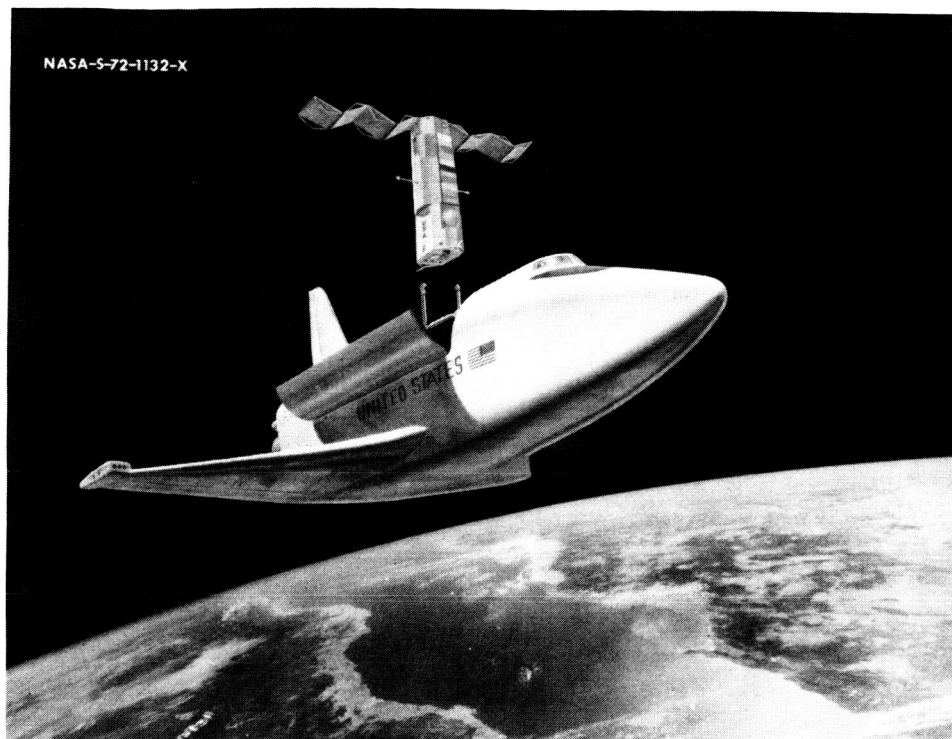


Figure 2-6

#### PAYLOADS THAT USE PROPULSION OR KICK STAGES

The benign launch environment of the space shuttle payload bay should also benefit the payload class that uses upper stages. The capability allows payloads to be placed into higher circular orbits, higher elliptical orbits, and trajectories for deep space probe missions. A family of these stages has been studied by NASA Centers and industry. The Lewis Research Center is currently evaluating six existing or modified candidate systems. Depending on the size of the propulsion stage selected, more than one stage can be used with a payload for a single mission. Also, instances may exist when more than one payload can be packaged with one stage or several stages. This capability makes for a highly adaptable approach for meeting experiment requirements with (1) a family of standardized propulsion stages for which the known interface with the payload bay is well understood, and (2) the operational software also as a part of the inventory.

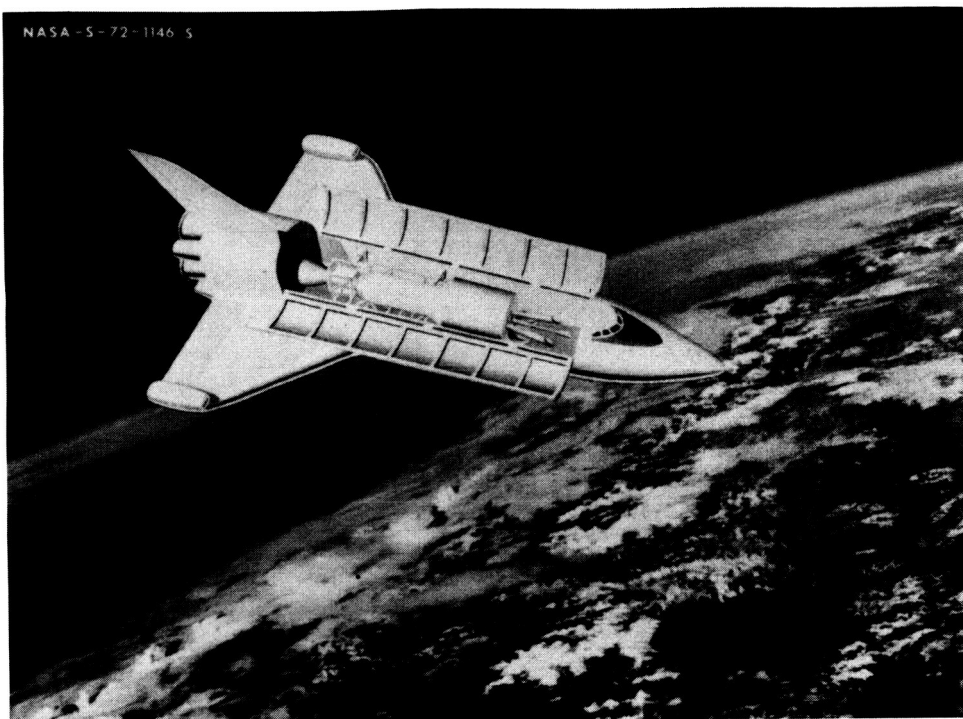


Figure 2-7

- REUSABLE WITH EXTERNAL EXPENDABLE ORBITER PROPELLANT TANKS
- REUSABLE BALLISTIC SOLID ROCKET MOTORS BOOSTER
  - PARALLEL BURN
  - WATER RECOVERY
- ORBITER AERODYNAMIC FLYBACK AND LANDING
  - 1100 N MI CROSS RANGE - DELTA WING ORBITER
- 15 FT DIA × 60 FT ORBITER CARGO BAY
  - 65 000 LB PAYLOAD IN DUE EAST ORBIT
  - 40 000 LB PAYLOAD IN POLAR ORBIT
- INTACT ABORT
  - 40 000 LB NOMINAL, UP TO 65 000 LB WITH REDUCED SAFETY FACTORS
- CABIN SHIRT SLEEVE ENVIRONMENT
- DEDICATED AVIONICS SYSTEMS
  - ATMOSPHERIC FLIGHT AND ORBITAL FLIGHT
- ORBITER MAIN ENGINES - THREE 470 K VAC THRUST HIGH PERF  $O_2/H_2$
- ORBITER FERRYING CAPABILITY
  - CRUISE ENGINES KIT - JP/AIR BREATHING
- OPTIONAL LIMITED CRUISE CAPABILITY FOR RETURN FROM ORBITAL MISSIONS

Figure 2-8. Space Shuttle Baseline System, Mar 72



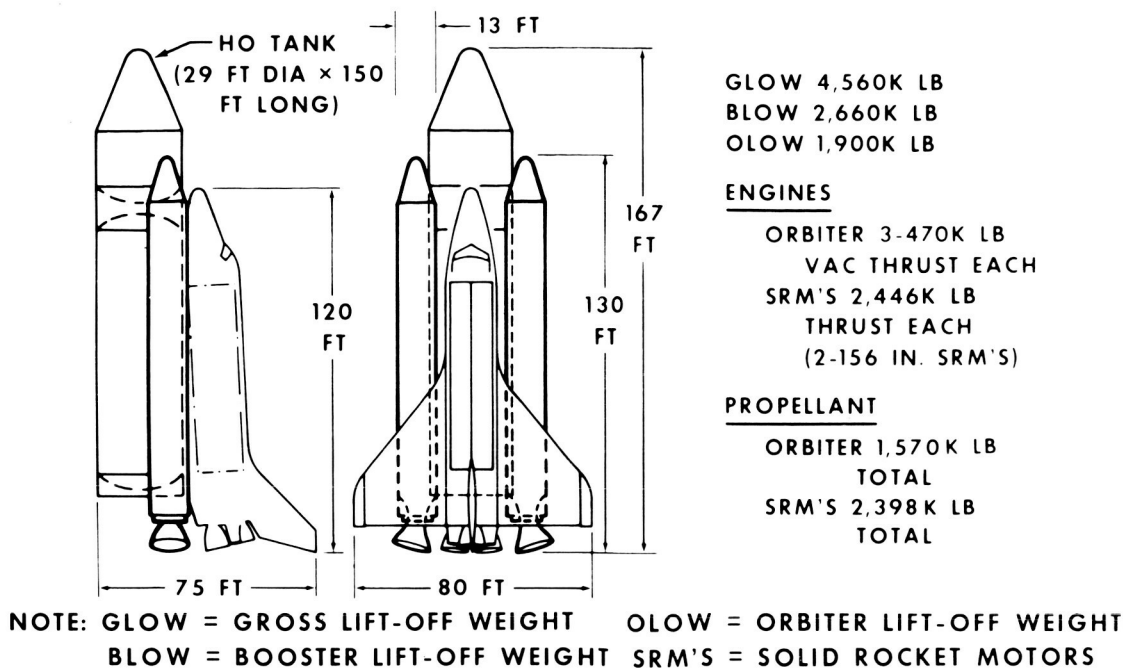


Figure 2-9. Space Shuttle System Parallel Burn

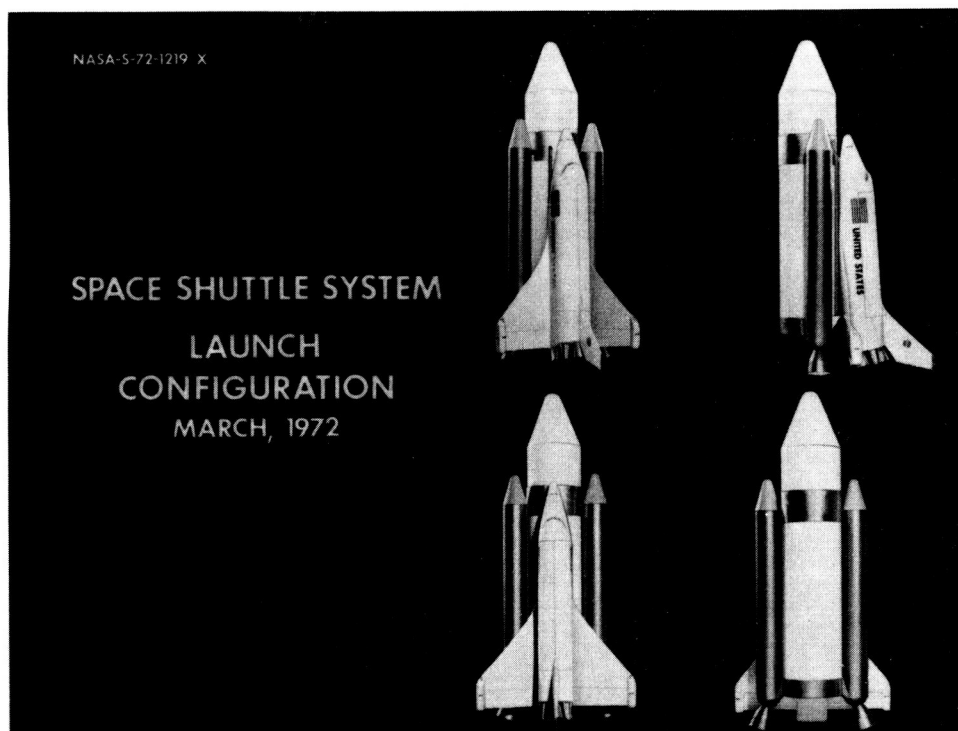


Figure 2-10

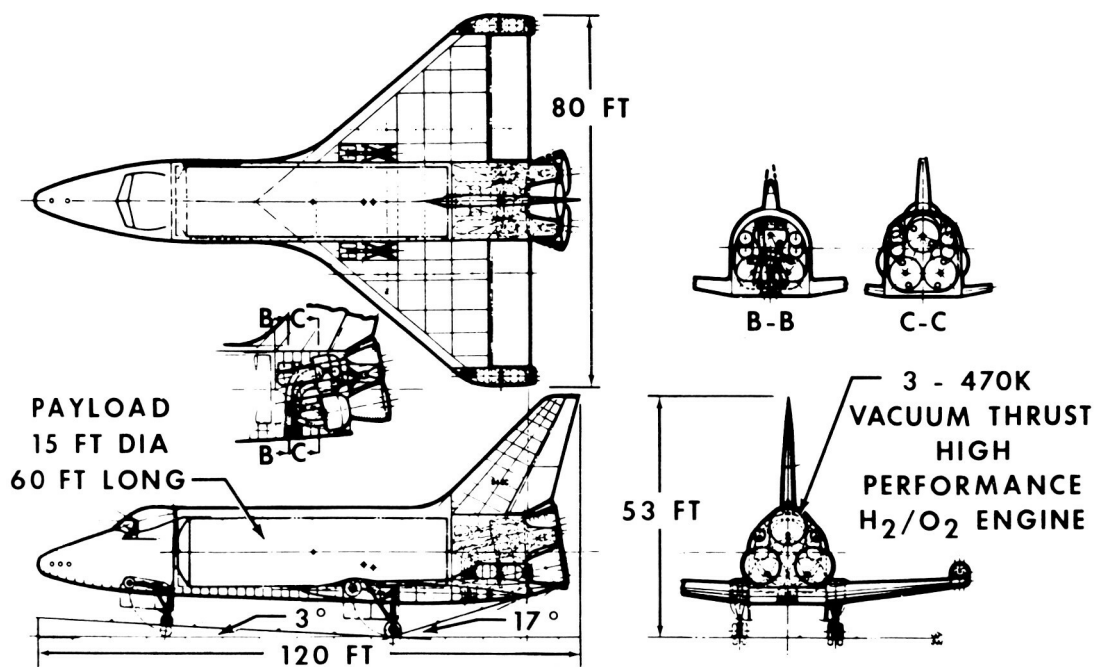


Figure 2-11. Space Shuttle External LH<sub>2</sub>/LO<sub>2</sub> Tank Orbiter Baseline – Feb 72

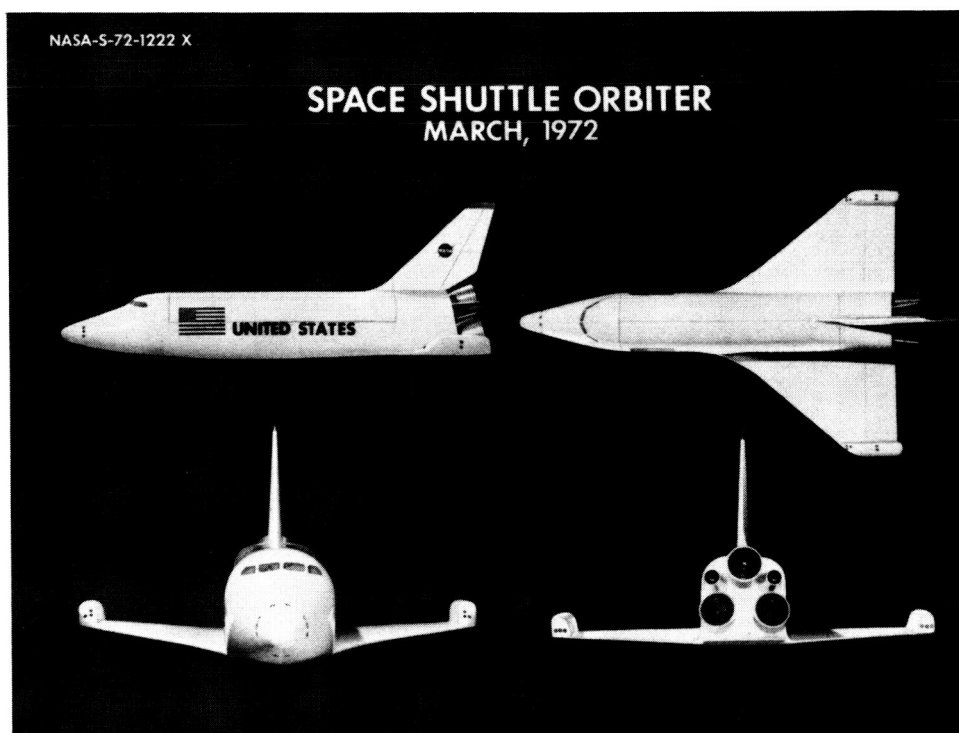


Figure 2-12

## POTENTIAL PAYLOAD SCHEDULE

The number of space shuttle flights for initial planning purposes was provided by the March 17, 1972, request for proposal (RFP). The schedule included six flights in calendar year 1978 (or the first 12 months); followed by 15, 24, 32, and 40 flights in 1979 to 1982, respectively; and 60 flights in 1983. This launch rate will be supported by an inventory of space shuttle systems for which the total number will not be known until later in the design phase. The delivery rate is also a variable.

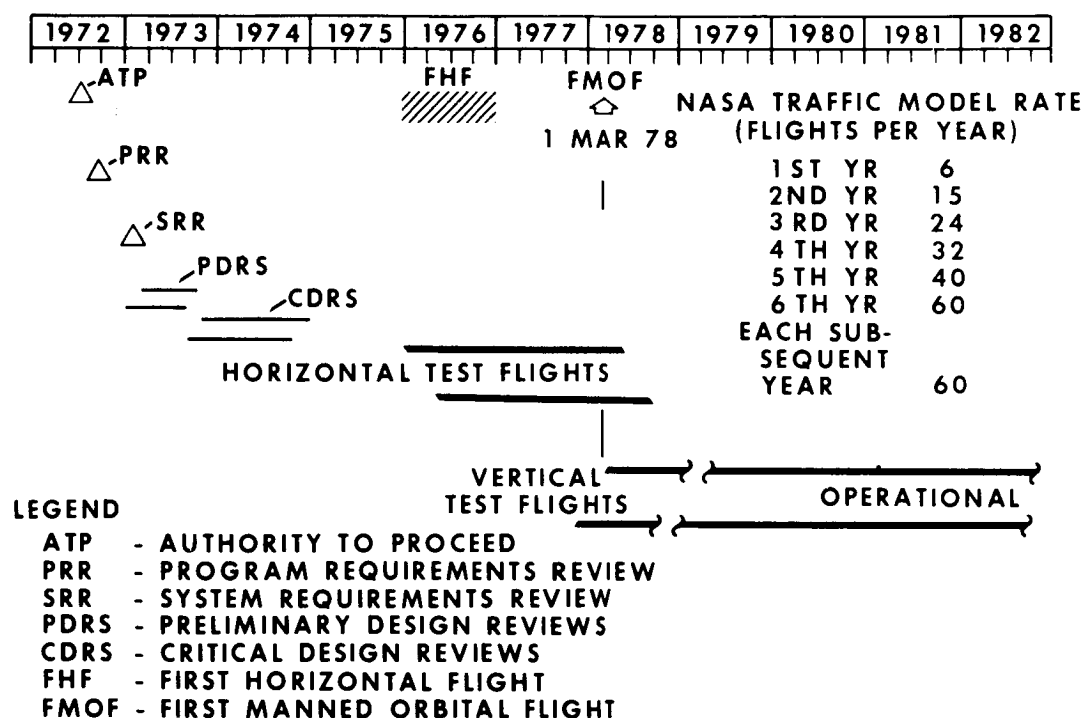


Figure 2-13. Space Shuttle Master Planning Schedule

## INTRODUCTION

This document describes the Space Shuttle system as it relates to payloads. Its purpose is to provide potential users of the space shuttle with a uniform base of information on the accommodations between the payload and the shuttle. By utilizing this information, preliminary payload planning and design studies can be evaluated and compared against a common set of shuttle/payload accommodations. This information also minimizes the necessity for each payload study to develop information on the shuttle configuration.

This document describes a baseline configuration of the space shuttle system which is consistent with current program requirements approved by the Space Shuttle Program Office, however, it should not be considered as a Shuttle Program Control or Requirements Document.

The Space Shuttle Program request for Proposal (RFP) Number 9-BC421-67-2-40P released to industry on March 17, 1972, with any subsequent provisions, is the primary and controlling source document for this issue. Parts of the RFP are repeated within both for continuity and to eliminate the need for many of the payloads community to request the RFP.

Summary level information on space shuttle configuration, preliminary performance data, and operation philosophy are briefly described. Information on payload interfaces, as related to shuttle operations, subsystems, environment, safety, and support equipment, is also included. The space shuttle preliminary design phase to be initiated soon will provide indepth information on orbiter characteristics.

Correspondence regarding Level I Program requirements, guideline, and planning should be addressed to NASA Hq. Items relative to general program requirements and intercenter program interactions should be addressed to the MSC Space Shuttle Program Office. Informal comments and questions on technical details should be addressed to the MSC Payloads Engineering Office. Please direct the inquiries to the following individuals —

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## GENERAL PAYLOAD ACCOMMODATIONS

### Capability/Characteristic

## Structural/Mechanical

Max. Payload Wt.	65,000 lbs
Max. Payload Wt. (Landing)	40,000 lbs nominal, up to 65,000 lbs with reduced safety factors
Payload Envelope	15 ft. dia. by 60 ft. length
Payload C.G.	Figure 2-1
Docking Port I.D.	1.0 meter
Docking Parameters	Lateral misalignment      +/-0.5 ft. Angular misalignment      +/-5.0 deg Roll misalignment          7.0 deg Closing Velocity            0.5 FPS
Payload Alignment in Bay	0.5 deg

## Electrical Power

Voltage	30 vdc nominal	
Load	Orbiter operation periods	1000 watts avg. 1500 watts peak

	On-Orbit coast periods	3000 watts avg. 6000 watts peak
--	------------------------	------------------------------------

Energy	50 kWh dedicated
--------	------------------

Source	Redundant dc busses in payload bay
--------	------------------------------------

#### Guidance and Navigation

Orbit Navigation Accuracies	STDN	1000 ft.
	Star/Horizon	4000 ft.
	Ground/Beacon	1000 ft.
	Horizon/Beacon	700 ft.
	TDRS	300 to 1000 ft.
	Landmark	2000 ft.

Rendezvous Range	300 N. miles with cooperative target
------------------	--------------------------------------

Attitude Pointing Accuracy	0.5 deg
----------------------------	---------

Stability Rate	TBD
----------------	-----

Deadband	0.5 deg, 0.1 deg
----------	------------------

#### Data Management

Computation	10,000 32 bit words
-------------	---------------------

Data Transfer	25,000 BPS via data bus
---------------	-------------------------

Data Downlink	265,000 BPS digital data, TV, and voice
---------------	---

Data Uplink	2,000 BPS
-------------	-----------

#### Environmental Control/Life Support

Personnel Accommodations	4 men, 7 days nominal
	42 man-days without system changes
	10 men with minor changes
	30 days with additional consummables

Cabin Atmosphere	14.7 psia 20 percent oxygen, 80 percent nitrogen 65 deg - 80 deg F controlled temperature Humidity control Contamination control Carbon dioxide control
------------------	--

Waste Management	Water storage 24 hours
------------------	------------------------

Active Thermal Control	Orbiter operations	5200 BTU/hr
	On-orbit coast	TBD

#### Payload Bay Environment

Acoustic	Less than 145 db overall
----------	--------------------------

Vibration	Less than current launch vehicle
-----------	----------------------------------

Acceleration	X	Y	Z
Launch	1.5+/-1.0	+/-0.25+/-0.5	+/-0.25+/-0.5
Max. Boost	3.0+/-0.25	+/-0.2 +/-0.25	+/-0.3 +/-0.25
Entry	-1	+/- 0.5+/-0.25	-3 +/-0.5

Thermal	Min (Deg F)	Max (Deg F)
*Prelaunch	+40	+120
Launch	+40	+150
On-orbit	-100	+150
*Entry + Postlanding	-100	+200

\*GSE Conditional air available

#### SPACE SHUTTLE VEHICLE

The space shuttle system consists of an orbiter with an external propellant tank and two solid rocket motors (SRM's). Figure 2-14 shows the shuttle system as the vehicles are combined for the launch and initial boost phases of the mission. Although the orbiter vehicle is reusable, its propellant tanks are expended on each mission.

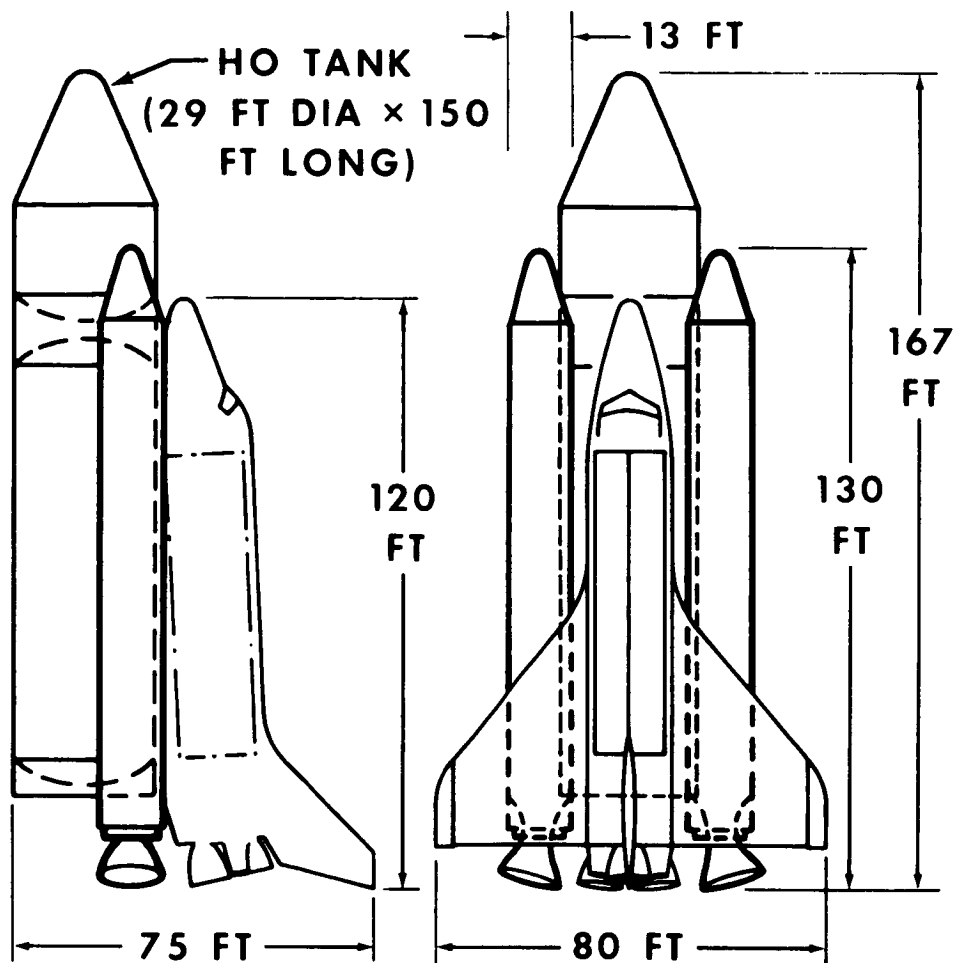


Figure 2-14. Space Shuttle System Parallel Burn

### ORBITER VEHICLE

The baseline orbiter is a manned reusable delta-winged vehicle (Figure 2-15). Contained within the main fuselage of the orbiter are the crew compartment, a payload bay capable of accommodating single or multiple payloads up to 15-foot diameter by 60-foot long, support subsystems, an orbital maneuvering system, and the main propulsion system engines. Protection against aerodynamic heating is provided during ascent and reentry by an external thermal protection system.

Aerodynamic flight is controlled through the elevons and rudder, while space-attitude control is accomplished through reaction control system thrusters which are attached to the vehicle as modules. To insure proper aerodynamic



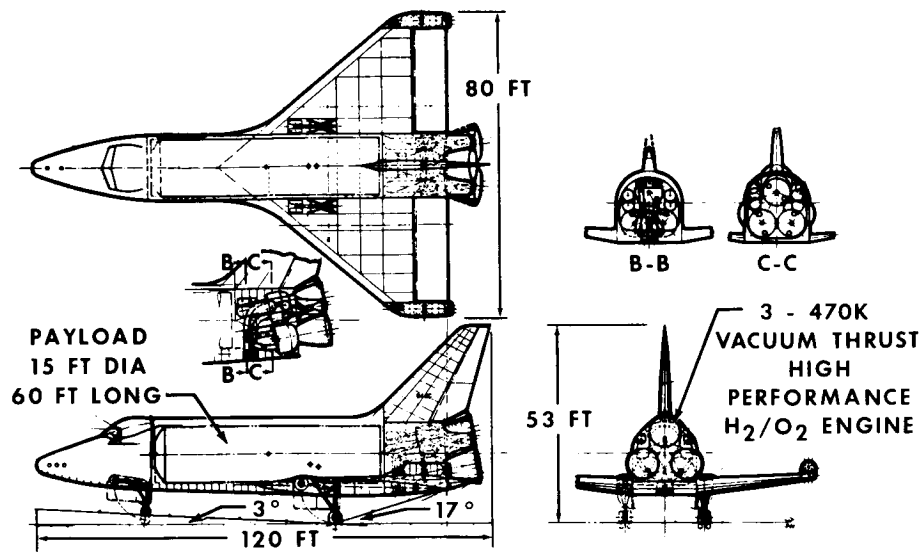


Figure 2-15. Space Shuttle Orbiter Baseline - Feb. 72

control during entry and atmospheric flight phases, the location of payload longitudinal center-of-gravity must be maintained within specified limits. Multiple sets of payload attachment points provide the capability to restrain and locate the payload within the orbiter within these limits.

Payload handling during orbital operations normally is accomplished by a standard deployment and retrieval mechanism. The concept selected for this baseline is a pair of manipulator arms attached to the forward bulkhead of the payload bay. These arms are stowed beneath the payload bay doors which open to disclose the full length and width of the payload bay. The manipulators perform multiple functions which include payload erection, deployment, retrieval, and stowage back in the payload bay. Manipulators also can serve to assist docking the orbiter with another orbiting element. Control of manipulators is accomplished by an operator located on the flight deck.

During orbital operations, payloads can be docked to the orbiter, remain within the payload bay, or be deployed and released from the orbiter. Airlocks and/or hatches are provided to permit shirtsleeve access to pressurized payloads and pressure suit access to the unpressurized payload bay.

The orbiter crew compartment houses the flight crew, passengers, controls and displays, as well as most of the avionics and environmental control system. An upper deck provides crew stations to accomplish all flight operations of the orbiter and control of the manipulator system. Provisions for payload

monitoring, passenger accommodation, electronics, and environmental control/life support systems are included on a lower deck. The entire compartment is temperature, pressure, humidity, and atmosphere controlled to provide a sea level type 'shirtsleeve' environment for the personnel and equipment. A crew of four can be accommodated in the pressurized cabin for a baseline mission duration of 7 days. Up to six additional persons can be accommodated for shorter duration missions with minor changes to the cabin interior. The orbiter design also has the capability to extend the orbital stay time up to 30 days. For missions in excess of 7 days, the weight of the expendables shall be charged against the payload.

The orbiter avionics system provides the functions for guidance, navigation, and control (for the orbiter and for the mated orbiter/booster), communications, limited avionics equipment performance monitoring and onboard checkout, electrical power distribution, conditioning and control, timing, and displays and controls. Certain of these capabilities can be time shared for support of payloads. These include capabilities for electrical power distribution and control, master caution and warning, navigational initialization, and communications. Orbiter avionic system also provides computation capability for data processing and control for limited functional end-to-end checkout of payloads.

## OPERATIONS

### PROGRAM OBJECTIVES

The basic objectives of the Space Shuttle Program are to develop a system which can economically deliver payloads to orbit, perform orbital operations, return from orbit, and be refurbished for reuse. The basic operational objective is to optimize shuttle subsystem design, ground dependence, and operations concepts to provide maximum probability of mission success at minimum program cost. Specific operational criteria are as follows —

- A. Long term combined storage and operational service life
- B. Total vehicle turn around time from orbital mission landing to launch readiness, less than 14 calendar days
- C. Design requirement of intact abort
- D. Baseline mission duration of 7 days
- E. Horizontal landing

## MISSION PHASES

Basically, the mission phases of the space shuttle system are prelaunch, launch, ascent, orbital operations, deorbit and landing, postlanding, and refurbishment. These phases represent the typical operational sequence illustrated in Figure 2-16.

**Prelaunch** — Prelaunch operations start with the initial checkout and preparation of the space shuttle for a particular mission. Payload detailed subsystem check-out and preparations are conducted independent of the orbiter preparations, and are completed prior to installation of the payload in the orbiter. Upon completion of the orbiter and payload independent checks, the payload is installed in the orbiter payload bay. Following payload installation, payload and orbiter system interfaces are verified for continuity and safety. Next, the orbiter with an external propellant tank is attached to the SRM's and vehicle interface checks are performed. In this configuration, the space shuttle system is mated to the launch umbilical tower for transportation to the launch pad.

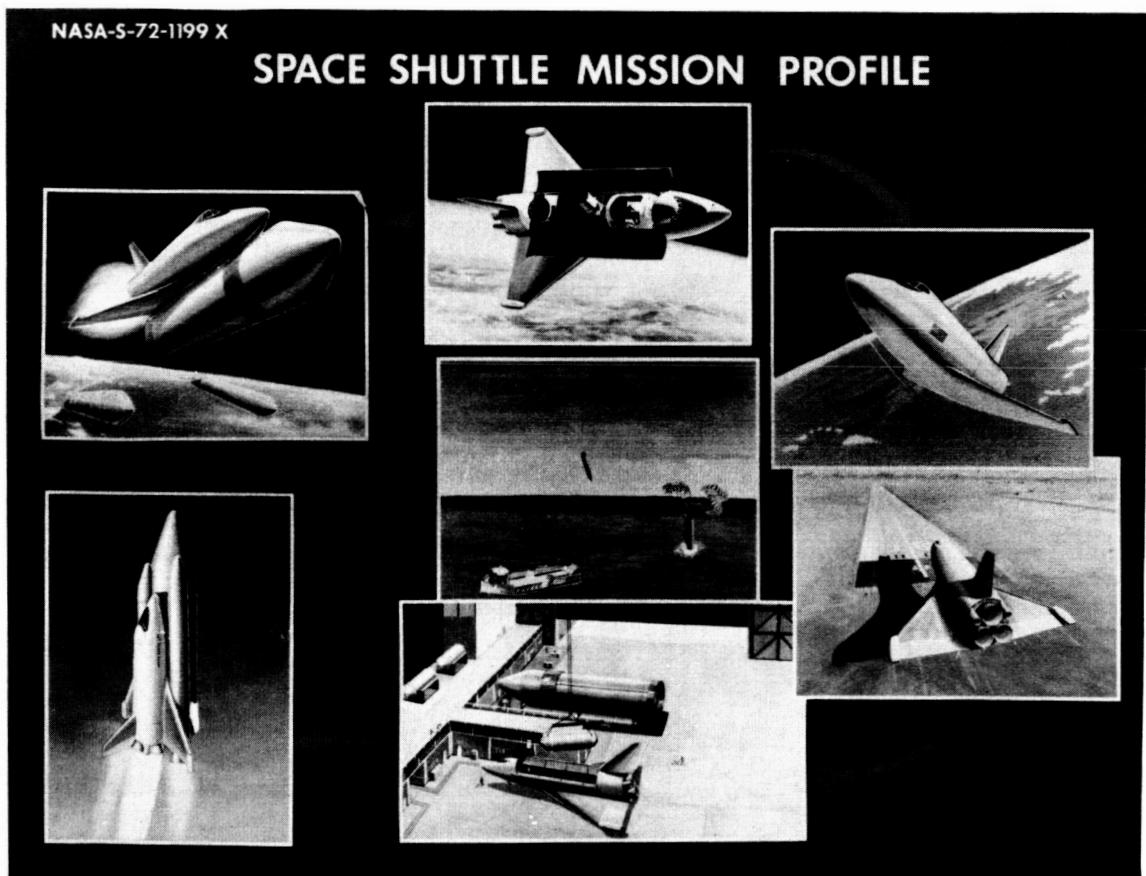


Figure 2-16

**Launch** — Following transportation to the pad, final launch readiness of the space shuttle system and final verification of the payload status plus loading of any time critical elements are accomplished. The crew and passengers enter for the terminal countdown and launch after the propellants are loaded.

**Ascent** — Liftoff initiates the mission sequence timers, and the SRM's and orbiter main engines propel the space shuttle to the desired staging velocity and altitude. At staging, the SRM's burn out, and the SRM cases separate from the orbiter. After the orbiter achieves low earth orbit, the orbiter main engines are shut down, the main tank is separated from the orbiter, and the tank is deorbited by a small retrorocket.

**Orbital Operations** — The orbiter orbital maneuvering system (OMS) engines burn the orbiter from the insertion orbit to the desired orbital position, or to a rendezvous with another orbiting element. Attitude control and critical translation maneuvers are performed by the orbiter reaction control system (RCS) thrusters. The RCS allows the orbiter to maintain the desired orbital attitude for payload operations, or to perform docking maneuvers. When the orbiter has attained the desired orbital position and attitude, the payload is readied for operations. Payload operations during the orbital mission phase may be performed with the payload still in the payload bay, attached to the orbiter, or deployed and released from the orbiter. Payload operations, which may require radio frequency (RF) and/or hardline interface between the payload, the orbiter vehicle, and sometimes the ground, are concerned with such functions as command and control, data transfer, monitoring and checkout, tracking and ranging, and inspection. Payload operations, which normally require some physical interface between the payload and the orbiter vehicle, are concerned with such functions as deployment, erection or release, logistics, maintenance, servicing, retrieval, retraction, and stowage. Payload deployment and retrieval operations generally will be accomplished by remote manipulator arms mounted to and supplied by the orbiter vehicle. These arms will be controlled from an operations station in the orbiter crew cabin with visual displays, floodlights, and preprogrammed computer controls to assist the operator during these operations. For payloads which remain attached to the orbiter, module deployment will be available if required. If erection or deployment is required, the manipulators or payload supplied special mechanical systems can be used.

**Deorbit and Landing** — Upon completion of the orbital operations, the orbiter is prepared for deorbit and entry. This event is initiated by the firing of the OMS engines to provide sufficient Delta-V to deorbit the orbiter, and orienting the orbiter to the proper angle of attack to accomplish entry. During reentry, the orbiter is protected by an external thermal protection system which insulates

structure and payload from the reentry aerodynamic heating. Following reentry, the orbiter changes attitude for atmospheric flight to the landing site. After acquisition of the landing site, the orbiter makes a final approach and horizontal landing.

Post Landing — Following landing, the orbiter is towed to the safing area where the crew and passengers disembark. After a cooldown period of (TBD), critical payload items may be removed from the payload bay or supported by ground support equipment (GSE). The orbiter and payload are then defueled and safed. Upon completion of the safing operations, the orbiter is towed to the maintenance and refurbishment building.

Maintenance and Refurbishment — In the maintenance area a recovered or non-deployed payload from the orbiter and returned to the payload service area, while scheduled refurbishment work is started on the orbiter subsystems. Typical items for orbiter refurbishment include select thermal protection system panels, environmental and life support system canisters and filters, and any maintenance item noted during flight. With the completion of the maintenance and refurbishment work, the orbiter is prepared for the prelaunch operations of the next mission.

## SHUTTLE ABORTS

A requirement of the shuttle is the intact abort and recovery of the crew, orbiter, and payload. To provide this capability, the shuttle has several abort modes available for the various phases of the mission.

The performance capability to meet this requirement is as follows —

- A. Crew and Passenger Insertion Through Launch Commit — The shuttle provides emergency egress for crew and passenger evacuation to a safe area in a maximum time of 2 minutes.
- B. Launch Commit Through Return-To-Site — The shuttle has the capability of intact abort and return to the launch site. Off-the-pad abort will utilize separate abort SRM's. The system design will include provisions for external tank separation and disposal.
- C. Return-To-Site Through Orbit Insertion — The orbiter has the capability (with one main engine out) to abort once around and return to the primary landing site from the point in the flight trajectory where a direct return to site capability ends.

- D. Orbital and Reentry — The abort made after orbit insertion will be early mission termination and return to a suitable landing site.

## PERFORMANCE

### PERFORMANCE CAPABILITIES

The referenced missions for the space shuttle are described in the following paragraphs and are given to define baseline performance capabilities only.

For performance comparisons, Missions 1 and 2 will be launched from Kennedy Space Center (KSC) into an insertion orbit of 50 by 100 nautical miles. Mission 3 will be launched into the same insertion orbit from the Western Test Range. The mission on-orbit translational Delta-V capability (in excess of that required to achieve the insertion orbit and that required for on-orbit and entry attitude control) is stated for each mission and includes on-orbit Delta-V reserves. The reaction control system (RCS) translation Delta-V required for each mission is used to accomplish all rendezvous and docking maneuvers after terminal phase initiation.

Mission 1 is a payload delivery mission to a 100 nautical mile circular orbit. The mission will be launched due east, and requires a payload capability of 65,000 pounds with the orbiter vehicle airbreathing engines removed. The purpose of this mission will be assumed to be placement and/or retrieval of a satellite. The orbiter vehicle on-orbit translational Delta-V requirement is 950 feet per second (FPS) from the orbital maneuver subsystem (OMS) and 120 FPS from the RCS.

Mission 2 is a resupply mission to an orbital element in a 270 nautical mile circular orbit at 55 degrees inclination. The rendezvous is accomplished using a 17-orbit ocelliptic rendezvous sequence (sequence is for reference only). The payload requirement is 25,000 pounds, with the airbreathing engines. The orbiter vehicle on-orbit translational Delta-V requirement is 1,400 FPS from the CMS and 120 FPS from the RCS.

Mission 3 is a payload delivery mission to a 100 nautical mile circular polar orbit and return to launch site in a single revolution. The payload requirement is 40,000 pounds with orbiter vehicle airbreathing engines removed. The orbiter vehicle on-orbit translation Delta-V requirement is 500 FPS from the OMS and 150 FPS from the RCS.

## PERFORMANCE ANALYSIS

The performance given is based on the most severe of the three reference missions, the delivery of a 65,000-pound payload to a 28.5 degrees inclination orbit. The current design approach for the orbital maneuvering system (OMS) is to have two sets of CMS tanks integrally mounted, having a total capacity of 1000 FPS with a 65,000-pound payload. Extra tankage can be installed to provide an additional 1500 FPS to meet the required 2500 FPS capacity. This additional tankage and propellants may be located in the payload bay.

## PERFORMANCE DATA

Figure 2-17 shows the shuttle payload versus inclinations for various circular orbital altitudes reached. The CMS propellant was loaded to the extent necessary

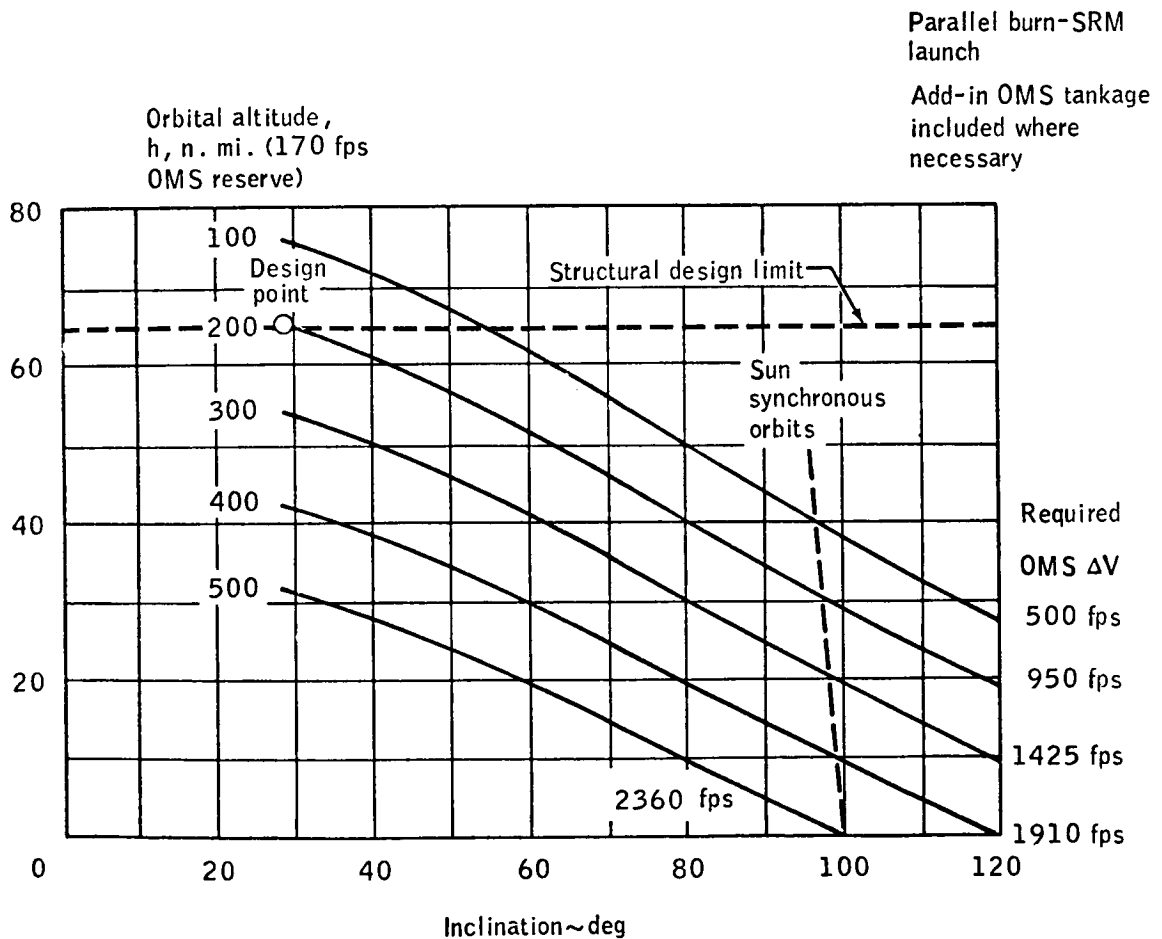


Figure 2-17. Payload Verses Inclinations

to provide exactly the on-orbit Delta-V required for each mission. This Delta-V is given at the right side of the figure for each curve as total CMS Delta-V. At the left of each curve is given the corresponding circular orbital altitude that the shuttle can reach, circularize at, and retrofire from, while maintaining a total of 170 FPS reserve for rendezvous and/or contingencies. The OMS is not used at any time in the launch phase, i.e., prior to the shuttle reaching the 50 by 100 nautical mile injection orbit. The total injected weight at any given inclination is a constant, and represents the maximum capability of the shuttle to that inclination. The variation in payload between altitudes is due to trading payload for OMS propellant.

Figure 2-18 shows payload as a function of circular orbit altitude reached, maintaining a 50 FPS OMS Delta-V reserve. For this plot insertion is always

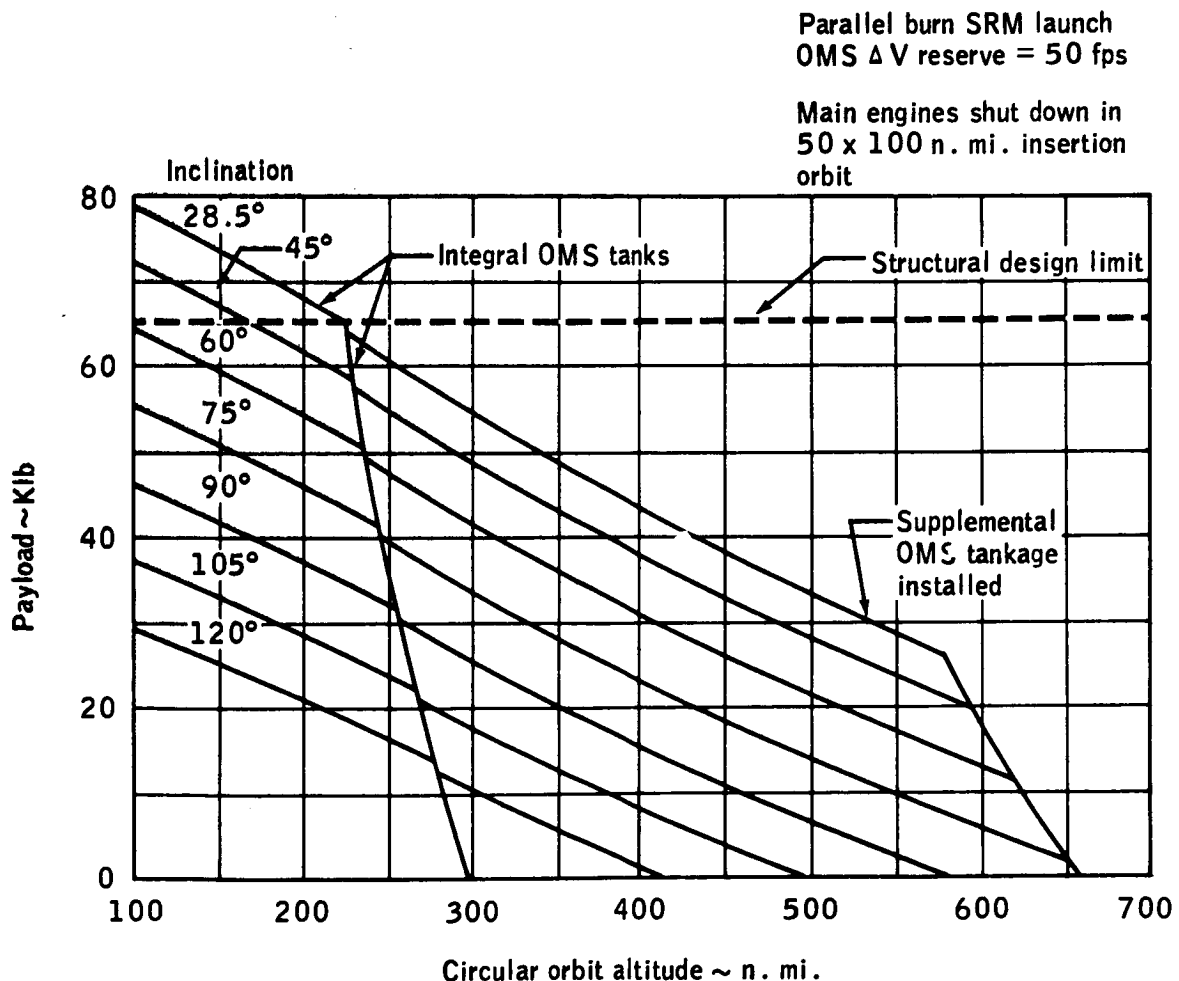


Figure 2-18. Payload Verses Circular Orbits Altitude



into a 50 by 100 nautical mile orbit, and any additional altitude is achieved by the OMS alone. All performance calculations are based upon carrying the entire payload throughout all of the Delta-V maneuvers. This would allow the vehicle to deorbit in the event that the payload for any reason could not be deployed. It would also be the case if one payload was delivered to orbit and another picked up for return to earth. For this figure payload is traded directly for OMS propellant until the OMS tanks are full. This figure does not include any rendezvous allowance. For rendezvous missions, 120 FPS extra OMS must be reserved for the rendezvous maneuvers. This reduces the circular orbital altitude that can be reached with any payload and any configuration by 25 nautical miles.

Figure 2-19 shows the capability of the shuttle to deliver payload to a high elliptical orbit. These data assume that the main engines are shut down in the nominal 50 by 100 nautical mile injection orbit. The disposable tank is then jettisoned and the orbit raised to 100 by 100 nautical miles with the OMS system. After this is done, the OMS system is then used to raise the apogee. The upper

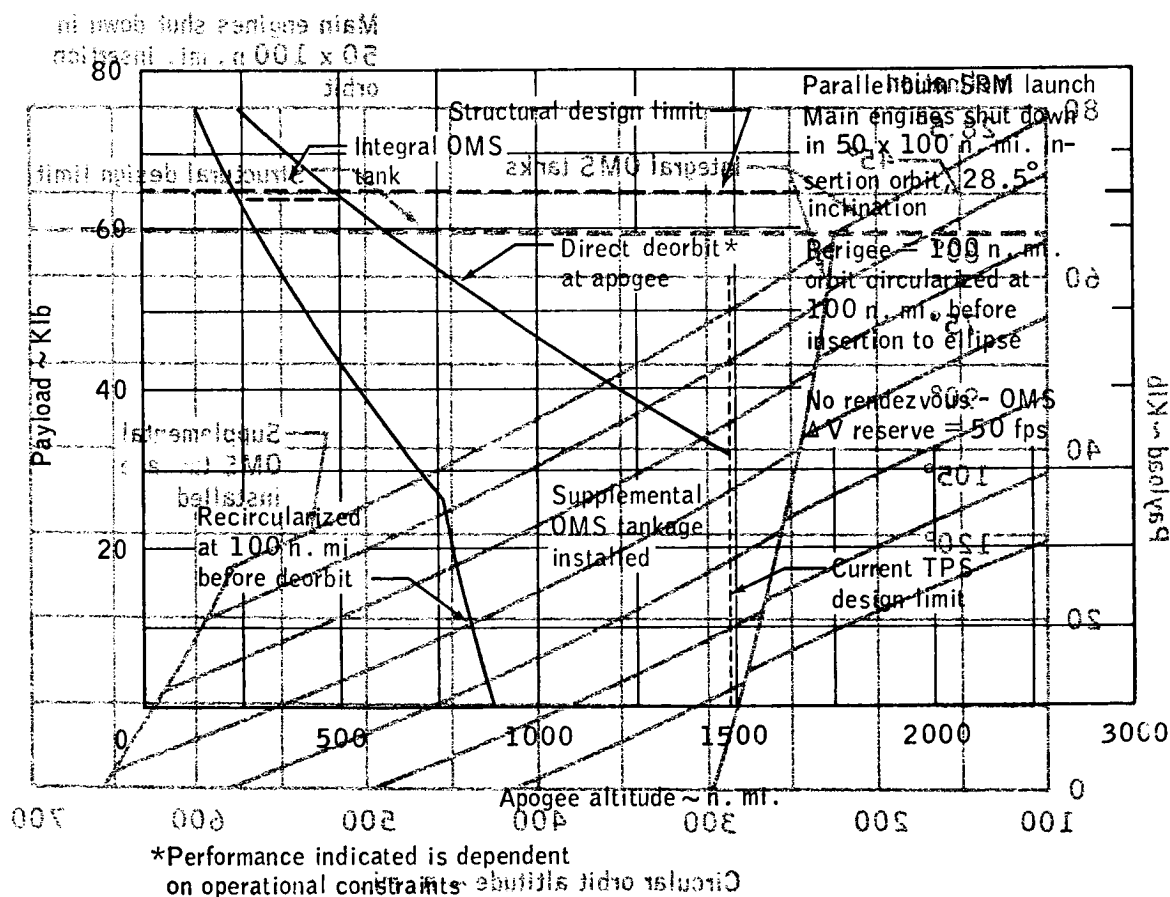


Figure 2-19. Payload Verses Elliptical Orbit Altitude

curve assumes a direct deorbit at apogee with reentry coming at perigee. This can be done in these cases where there is no specific requirement on the positioning of the apsides of the ellipse. In that case, the orientation can be selected to allow the proper apsidal position for direct entry from apogee. The bottom curve is for those cases where the shuttle must recircularize at 100 nautical miles before deorbit. This would be the case if some particular apogee position were required for the payload where entry were not possible at perigee.

With the shuttle launched into a high ellipse, a payload satellite could be placed into a circular orbit at apogee altitude with a single burn of a third stage. This would allow the use of a single simple propulsion stage on the payload.

0.7 0.8 OPERATIONAL INTERFACE 0.9 1.0

## PRELAUNCH OPERATIONS

**Payload Checkout** — Incoming payloads and experiments will be received at the payload service area where final payload inspection checkout, and integrated tests will be performed. If the installation of an individual experiment into a payload is required, it will be accomplished in this area. Any deficiencies discovered during these operations will be corrected prior to installation of the payload into the orbiter.

The concept of payload checkout and assembly provides maximum flexibility for the various payload requirements and decouples the operational orbiter vehicle checkout from the payload checkout. This is accomplished by the use of structural interface fixture for physical and mechanical orbiter/payload interface checks, and with electronic analog units for electrical power, data management, control, and communication interface checks between the orbiter and the payload.

## ORBITER PRELAUNCH OPERATIONS

During all phases of the prelaunch operations, special emphasis will be placed on contamination control procedures to protect sensitive payload elements.

**Payload Center of Gravity** — Precise information on the payload mass center-of-gravity (C.G.) must be established prior to installation of the payload in the orbiter. For aborts and entry, the payload C.G. is restricted in the longitudinal axis to the envelope shown in Figure 2-20.

**Payload Installation** — The installation of the payload into the orbiter may occur at either of two facilities — the Shuttle Maintenance and Refurbishment Facility (SMRF), or the Vertical Assembly Building (VAB). The capability to change out payloads on the pad will exist for contingency purposes only and should not be considered as a normal or planned operation. Normally, the payload is inserted

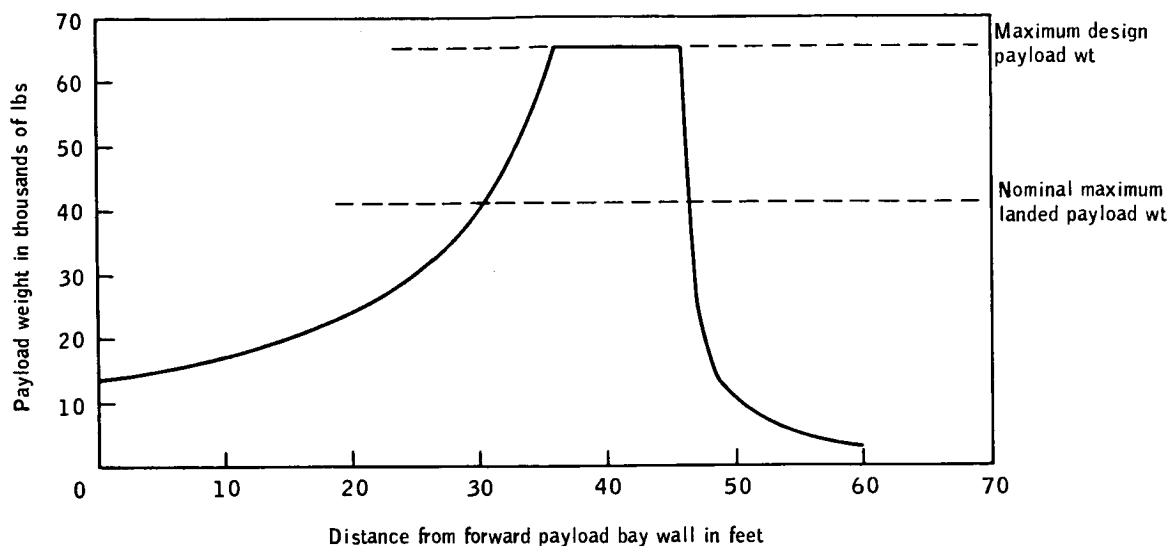


Figure 2-20. Payload Longitudinal Center-of-Gravity Limits

into the orbiter payload bay while the orbiter is in the horizontal position in the MRF. Following installation and establishment of electrical and other interfaces, validation of these interfaces is accomplished.

**Vehicle Integration** — The next phase of prelaunch operations involves the mating of the orbiter and the SRM's. The payload prelaunch operations must be basically completed since access to the payload is limited to payload monitoring via shuttle systems except under special circumstances. With the shuttle in the vertical position and final interface checks complete, the shuttle is ready for prelaunch operations.

### ORBITER PRELAUNCH OPERATIONS

**Launch Preparation** — The vehicle operations are devoted primarily to verifying the launch umbilical tower/launch facility connections, performing the final integrated tests, servicing the vehicle, loading the crew and passengers, and final closeout. Figure 2-21 is a representative flow of activities during this period. Although payloads nominally are loaded prior to the orbiter/booster mating, it is possible to replace the payload on-pad in contingencies. Hazardous servicing procedures are also conducted during this period, if there are such requirements. Access to the payload while on the pad normally will be limited to those items accessible through the orbiter crew compartment or through the payload bay door. The access, removal, and loading of payload equipment on the pad will be limited to not more than 10 hours elapsed time prior to T-2 hours.

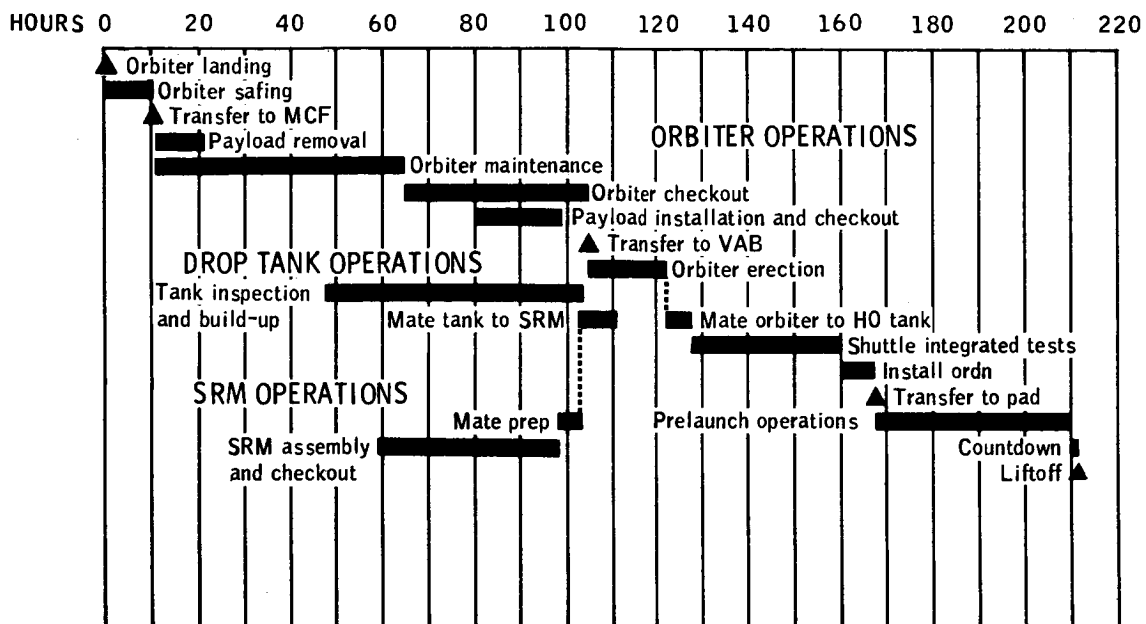


Figure 2-21. Orbiter Turnaround Operations Timeline

**Payload Services** — Payload services are furnished through standard orbiter/payload interfaces and through payload access panels. Standard ground and launch services may be supplemented by reconfiguration of an access panel to accommodate unique payload services. However, the reconfiguration of access panels and support of unique services are charged to the payload.

Normally, the orbiter/payload interfaces provide power, communications, status monitoring, atmosphere control, venting, and certain payload propellant access provisions. The payload services for cryogenic propellants include access for fill, vent, drain, and dump. Atmosphere control of the payload bay is provided through GSE during prelaunch operations, primarily to keep the bay free of contamination by external sources.

## FLIGHT OPERATIONS

**Shuttle Ascent** — The lift-off to insertion phase will be essentially an automatic operation under orbiter control. The early vertical flights will have ground support for trajectory and systems much like that existing for Apollo. After the shuttle operations mature, there will be less need for real-time shuttle systems support for launch. During launch, the payload support will be limited primarily to minimum subsystems support and payload safety status monitoring.

**Payload Control and Display** — The orbiter will have provisions for monitoring all safety-of-flight parameters generated by the payload. These parameters are displayed to the flight crew and mission specialists. In addition to the safety-of-flight parameters, payload peculiar parameters can be displayed to the mission specialist on the general purpose displays, or through payload supplied mission peculiar displays to the payload specialist.

**Payload Checkout** — Prior to payload operation or deployment, functional checkout can be accomplished by use of programs stored in the memory of the computer used for payload checkout. Manual insertion of payload data/commands into the computer can be made through the keyboard. Dedicated payload displays and controls can also be used in conjunction with payload checkout. Visual inspection and manual assistance by the crew can be accomplished by extra-vehicular activity (EVA) or intravehicular activity (IVA). When the orbiter docking port is secured to a docking port on another orbital element, shirtsleeve access is available through the orbiter airlock and docking port to the orbital element. Verification of docking and undocking is displayed to the orbiter flight crew.

**Payload Deployment and Retrieval** — The orbiter provides a payload deployment/retrieval mechanism to deploy payloads clear of the orbiter mold line. For retrieval, this mechanism interfaces with payloads designed for retrieval and, after attachment to the payload, aligns the payload in the payload bay for secure stowage of the payload. In addition, this mechanism is capable of supporting the payload in the deployed position under attitude stabilization and docking loads.

**Deployment of spin-stabilized payloads** may be accomplished from a spin table provided by the payload. Any additional payload peculiar deployment, erection, retraction, et cetera, requirements for special mechanical systems is provided by the payload.

**Multiple Payload Deployment** — The orbiter will have the capability to deploy multiple-payloads on-orbit during a single mission, including placement or docking of payloads to a stabilized body. For multiple-payload missions the orbiter subsystems support capability is shared by the payloads.

**Docking** — Docking of the orbiter to a payload or another orbital element can be accomplished with the orbiter manipulator arms and docking port, or by direct docking. Primary command and control authority remains with the orbiter during the docking operations. To accommodate docking, the orbiter orients and approaches the orbital element with the use of the orbiter RCS. When the orbiter is within the reach distance of the manipulator arm of the

orbital element, the manipulators engage the orbital element and draw the two bodies together to accomplish connection of the docking interfaces. For direct docking, the orbiter as the active vehicle approaches and engages the docking mechanisms on the orbital element by impact engagement. The operational design parameters for docking are given in Table 2-I.

Table 2-I  
Operation Design Parameters for Docking

Lateral Misalignment	+/-0.5 Feet
Angular Misalignment	+/-5.0 Degrees
Roll Misalignment	7.0 Degrees
Closing Velocity at Contact	0.5 FPS
Active Vehicle Angular Velocity at Contact	1.0 Deg/Sec
Passive Vehicle Angular Velocity at Contact	0.1 Deg/Sec

When the orbiter docking port is secured to a docking port on another orbital element, shirtsleeve access is available through the orbiter airlock and docking port to the attached element. Verification of docking and undocking is displayed to the orbiter flight crew.

EVA/IVA - To distinguish between extravehicular activities (EVA) and intra-vehicular activities (IVA) with regard to a pressure suited crewman, the following definition is given.

EVA applies to activities conducted outside the spacecraft pressure hull or an open payload bay. IVA by a pressure-suited crewman, is confined by the vehicle structure. Activities within the payload bay with the doors closed are considered IVA. If a section is applicable to EVA only, IVA will be excluded by a note. Otherwise, the term EVA will be used to include IVA.

The orbiter provides the capability to perform multiple EVA's in orbit, or IVA's into the payload bay. However, the expendables and EVA suits are provided at the expense of payload weight. Two crewmen EVA is considered the normal EVA mode of operation where one crewman performs the EVA task, the second crewman maintains a backup status, and both EVA crewmen are monitored from within the orbiter. EVA is a method for the on-orbit payload activities, and its usage for both normal and contingency payload operations must be traded against the advantages and disadvantages of alternate methods. It is possible that for some tasks, EVA could be a highly cost effective method for performing payload operations.

Communications — A communication satellite system is available for relay of voice and video between the orbiter and ground. The orbiter is also capable of direct communication with the ground. The orbiter/payload communication interfaces are given in Tables 2-IIA and 2-IIB. These interfaces provide available communication channels for payload operations during a mission. Communication requirements in excess of these are supported by the payload.

Table 2-IIA  
Orbiter/Payload Communication Interfaces

Signal Description	Hardwire Payload Interface	
	Orbiter Equipment	Payload Equipment
<u>Voice</u>		
Intercom	Audio Center	Audio Comm Panel
<u>TLM</u>		
Interleaved TLM	Stored Program Processor	Remote MUX Unit
Direct TLM	Modulator/Demodulator	PCM Encoder
Wideband Analog	Wideband Xmtr	FDM Equipment
Wideband PCM	Wideband Xmtr	PCM Encoder or Recorder
TV Video	Wideband Xmtr	TV Camera
<u>Commands</u>		
Attached Payload Commands	Computer	Payload Decoder
<u>TV</u>		
Camera Video	Video Display Unit	TV Cameras
Camera Control	Video Control Unit	TV Cameras

Table 2-IIB  
Orbiter/Payload Communication Interfaces

Signal Description	RF Payload Interface	
	Orbiter Equipment	Payload Equipment
Voice		
Duplex	VHF Transceiver	VHF Transceiver
TLM		
Data	PCM Receiver	PCM Transmitter
Commands		
Detached Payload	Transmitter Signal Formatter	Receiver Signal Processor
Ranging		
Detached Payload	Transceiver Digital Ranging Generator (DRG)	Transceiver Range Tone Transfer Assy (RTTA)

### CREW

The basic orbiter crew size is four, two of which are the commander and pilot who usually accomplish the flight operations of the orbiter. The following nomenclature is used to identify and describe the duties of the personnel.

**Commander** — The commander is in command of the flight and is responsible for overall space vehicle, payload flight operations, and vehicle safety. He is proficient in all phases of vehicle flight, payload manipulation, docking and subsystem command, control, and monitor operation. He is also knowledgeable of payload and payload systems as they relate to flight operations, communication requirements, data handling, and vehicle safety.



Pilot — The pilot is second in command and is equivalent to the commander in proficiency and knowledge of the vehicle.

Mission Specialist — The mission specialist is responsible for interfacing of payload and orbiter operations and the management of payload operations. The specialist is trained in vehicle and payload subsystems, flight operations, and payload communications data management. More than one mission specialist may be included in the crew.

Payload Specialist — The payload specialist is responsible for the applications, technology, and science payload/instruments operations. This specialist has detailed knowledge of the payload/instruments, operations, requirements, objectives, and supporting equipment. More than one payload specialist may be included in the crew.

Passenger/Observer — Passenger/observers are personnel who are onboard, but have no active part in shuttle operations.

Crew Provisions — Volume is available within the crew compartment for additional payload specialist or passengers, however, their weight, personnel support systems, equipment, and consumables are charged to the payload. Also, within the crew compartment are sleep provisions to allow crew rotation for 24-hour operations. Payload operations may elect either multiple shifts or discrete working hours to support mission objectives.

## POSTFLIGHT OPERATIONS

Following landing, the orbiter is towed to the safing facility where the crew and passengers disembark and the necessary postflight cooldown and safing operations are performed. Normally, the payload will remain with the orbiter unless there are critical experiments which must be removed at this facility. This facility can also be used to safely and purge hazardous payload items. The payload must be compatible with the available shuttle GSE, or supply the necessary equipment to support the operation.

When the safing operations are completed the orbiter is towed to the MRF where the payload is normally removed from the orbiter.

## SYSTEM/SUBSYSTEM INTERFACES

### STRUCTURAL/MECHANICAL INTERFACES

Payload Bay Envelope — The orbiter payload bay can accommodate a payload, or combinations of payloads, whose dynamic envelope is equal to, or less than,

60 feet in length and 15 feet in diameter. This payload envelope excludes the necessary payload structural attachment points, which extend outside the envelope to interface with the orbiter structural mounting points. Clearance envelope between the payload envelope and the orbiter structure is provided by the orbiter to avoid orbiter deflection and deployment interference between the orbiter and payload.

**Payload Structural Attachment** — Multiple standardized attachment points are located (TBD) in the payload bay to structurally support all payloads. The locations of these points are at or outside the 15-foot diameter payload mold line and transmit payload loads to the orbiter primary structure. These attachment points interface with the payloads or payload adapters and are capable of supporting the payload under all mission phases. The orbiter has the capability to land 40,000 pound payloads with nominal wind and load factors (airbreathing engines removed) and larger payloads with reduced structural safety factors.

The orbiter also provides the capability for determining the mechanical alignment of the payload (with respect to the reference frame of the orbiter) to an accuracy of 0.5 degree in all axes while the payload is attached to the payload bay.

**Remote Manipulator System (RMS)** — The orbiter payload deployment and retrieval mechanism consists of a pair of remote manipulator arms which are stowed outside the payload volume. Figure 2-22 is a preliminary design of a typical system. Payload engagement is accomplished through terminal devices on the end of each arm.

To accommodate payload retrieval and stowage in the payload bay, the payload provides the orbiter compatible mechanical, electrical, and fluid interfaces.

**Docking Mechanism** — The docking mechanism is designed to interface with standardized docking mechanisms on other orbital elements and on another orbiter. The docking mechanism contains all the necessary hardware for engaging, latching, and sealing the interface between the orbiter and another orbital element. Included in the orbiter are appropriate displays for verification of the engagement and separation of the docking interface. Within the diameter of the docking ring are a clear passageway of 1.0-meter diameter and the necessary power, caution and warning, data, communication, and fluid interface connectors to support docked orbital operations.

**Payload Bay Door(s)** — The orbiter has the capability to expose the entire length and the full width of the payload bay. With the payload bay door(s) and radiator(s) open, the unobstructed 180-degrees lateral field-of-view is available.

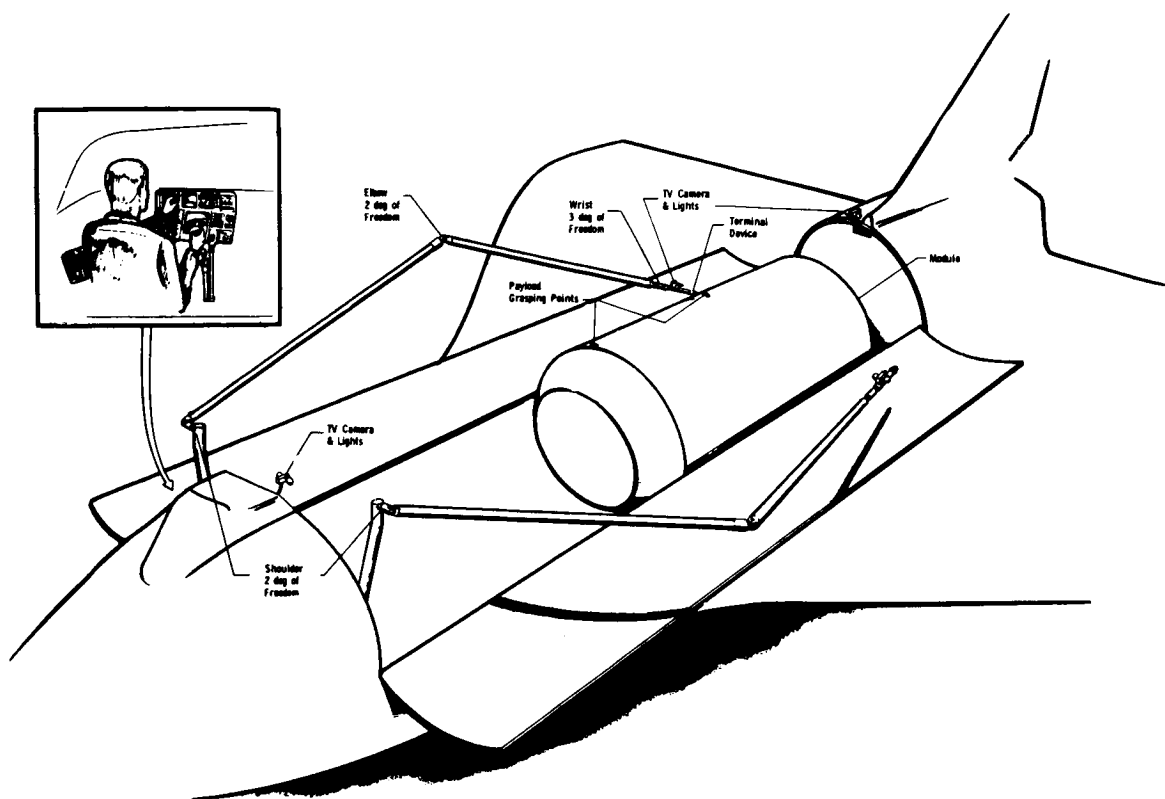


Figure 2-22. Remote Manipulator System

to the payload at the plane of the hinge line, which is located (TBD) relative to the longitudinal centerline of the payload bay.

**Payload Bay Service Panels** — Payload bay service panels are placed at discrete locations in the orbiter structure for GSE service access to the payload. These panels, located in the payload bay walls, normally are blank, nonstructural panels which are capable of being replaced with payload peculiar panels designed to service a particular payload. The weight difference between the blank service panel and the payload peculiar panel is charged against the payload weight. The lines connecting the payload to the service panel also are charged against the payload weight.

#### FLUID SYSTEM INTERFACES

**OMS Delta-V Kit** — On-orbit maneuvering Delta-V in excess of the 1000-FPS available in the baseline orbiter is available by addition of OMS propellant.

The added volume and weight for propellant, tankage, and plumbing to the vehicle OMS is charged to payload.

**Propulsive Payload Interfaces** — Propulsive stages carried within the payload bay require various types of fluid interfaces between the orbiter vehicle and the payload bay. These interface requirements vary significantly with the types of propellant utilized by the propulsive stage. Storable propellants, such as those used by the Agena, Delta, and transtage can be loaded prior to stage integration with the orbiter. No fill connections, therefore, are required but drain connections can be required for emergency dump. Several options appear feasible for providing the fluid interfaces previously mentioned.

Fluid connection panel(s) are located to minimize vehicle scar weight. These interface panels provide the fluid servicing plus the venting locations. The propulsive payload propellants require venting as would, in most cases, the pressurants. For these cases, the fluid connection panels are fitted for the payload. When not required, the service panels are replaced by blank panels. Propellant service umbilicals and dump provisions are required for cryo payloads.

Table 2-III indicates the servicing applicability for each class of payloads fluids. The 'Open Payload Bay Door' is servicing payloads when the bay doors are opened. Cryo services are not included since the doors are closed prior to launch, however, a dump system is required.

Table 2-III  
Loading and Dumping Options

	CMS Integration	Removable Service Panels	Open Payload Bay Door
OMS Kit	X	X	X
LDX/LH2		X	
Earth Storable		X	X

**Payload Bay Vents** — Adequate penetration for venting and purging the payload bay and active payload effluents are provided by the orbiter. This vent system consists of nonpropulsive vents.

## ELECTRICAL POWER

Electrical power for payloads is available from the orbiter electrical power system. An electrical energy allowance of 50 kilowatt-hours (KWH) is dedicated for payload support with energy in excess of this allocation being mission dependent and capable of being supplemented by additional consumables to the orbiter fuel cells and/or by independent payload systems. This power is in the form of regulated redundant dc power having the characteristics shown below:

Voltage — 30 vdc nominal

Transient (TBD)

Load — 1000-watts average; 1500-watts peak (peak orbiter operation periods)

— 3000-watts average, 6000-watts peak (on-orbit coast periods)

Extended Duration Mission Support — For extended duration missions, or for missions requiring increased total electrical energy, additional fuel cell reactants are required and are plumbed in from the payload bay. These consumables, their tankage, and the plumbing to the orbiter interface are charged to the payload. The extended duration mission requires added consumables for the payload and for operation of the orbiter beyond the normal 7-day orbiter mission.

## DISPLAYS AND CONTROLS

Displays and controls for payload operations are provided at the commander/pilot, mission specialist, and payload handling stations.			
Payload displays and controls at the commander/pilot stations are primarily concerned with communications, power control (master circuit breaker control switch for payload power), and a payload master caution and warning light.			

Displays and controls provided at the mission specialist station include —

- Master caution and warning
- Caution and warning panel with dedicated wiring for displays

C. A cathode ray tube (CRT) and keyboard for control of payload monitoring and checkout in conjunction with the computer used for payload monitoring

D. Space for displays and controls provided by the payload

E. Audio communications panel with audio-channel selector for communications with crewmen, personnel in payload bay, EVA personnel, personnel in a free flying payload, or the ground

(24) Personnel in a free flying payload	(24) Personnel in the ground	System
The payload handling station displays and controls are designed to support payload deployment, docking, retrieval, and remote operations through the use of the manipulator arms. Specific displays and controls of this station include the following items —		
A. Manipulator control system and payload retention controls and displays	1000	Ground Beacon
B. Displays for payload bay TV video, and controls for operating and supplying power to the payload bay cameras	100	Horizon Beacon
C. Audio communication panel with audio channel selector for communications with crewmen, payload bay, EVA personnel, and ground		JDRS

D. Caution and warning displays for general payload operations items

E. Payload bay lighting controls for illumination of payloads, payload bay area, and payload interfaces

## GUIDANCE AND NAVIGATION

## STABILIZATION AND CONTROL

**System Capabilities —** The orbiter guidance, navigation, and control (GN+C) system is capable of providing guidance, navigation, and control for the orbiter through all phases of orbital space flight from launch through entry, and for aircraft aerodynamic flight modes. During the on-orbit phases, the guidance and navigation of the orbiter can be independent of direct ground support.

**Rendezvous —** The orbiter has the onboard capability to rendezvous with an in-plane cooperative target up to 300 nautical miles, and is the active vehicle during rendezvous, docking, and undocking. The orbiter is also capable of manual docking with other orbiters or compatible orbital elements during day-light or darkness. By using ground facilities and other aids, the orbiter is capable of rendezvous with and retrieval of a passive stabilized orbiting element.

Orbit Navigation — Table 2-IV presents a summary of estimated navigation performance for some of the possible systems.

Table 2-IV  
Typical Navigation System Accuracies

System	RMS Position (FT)	RMS Velocity (FPS)
STDN	1000	1
Star/Horizon	4000	2
Ground Beacon	1000	1
Horizon/Beacon	700	1
TDRS	300 to 1000	1
Landmark	2000	2

Orbiter/Payload Data Transfer — Information from the GN+C computer subsystem can be transferred to the payload bay via hardwire. As a minimum, the information will include timing, state vector initialization and extrapolation (if desired), and spacecraft attitudes and attitude rates.

#### STABILIZATION AND CONTROL

Payload Pointing Accuracy — The dominant errors involved in pointing a payload with the spacecraft systems are contributed by the structural misalignments and thermal distortions. The guidance and navigation (G+N) subsystem errors, including an equivalent angular error due to navigation uncertainty are less at 0.2 degree (1 sigma). Control system errors, i.e., attitude deadband excursions, must also be added to the stated error sources.

The orbiter is capable of pointing the payload continuously for one orbit every other orbit for one 24-hour period per mission at any ground, celestial, or orbital object within +/-0.5 degrees. Payload requirements in excess of this capability should be provided by the payload or experiment systems.

Reaction Control System — Figure 2.23 shows thruster locations in the wing tip/nose configuration. Current thruster sizing yield the stability rates indicated in Table 2-V.

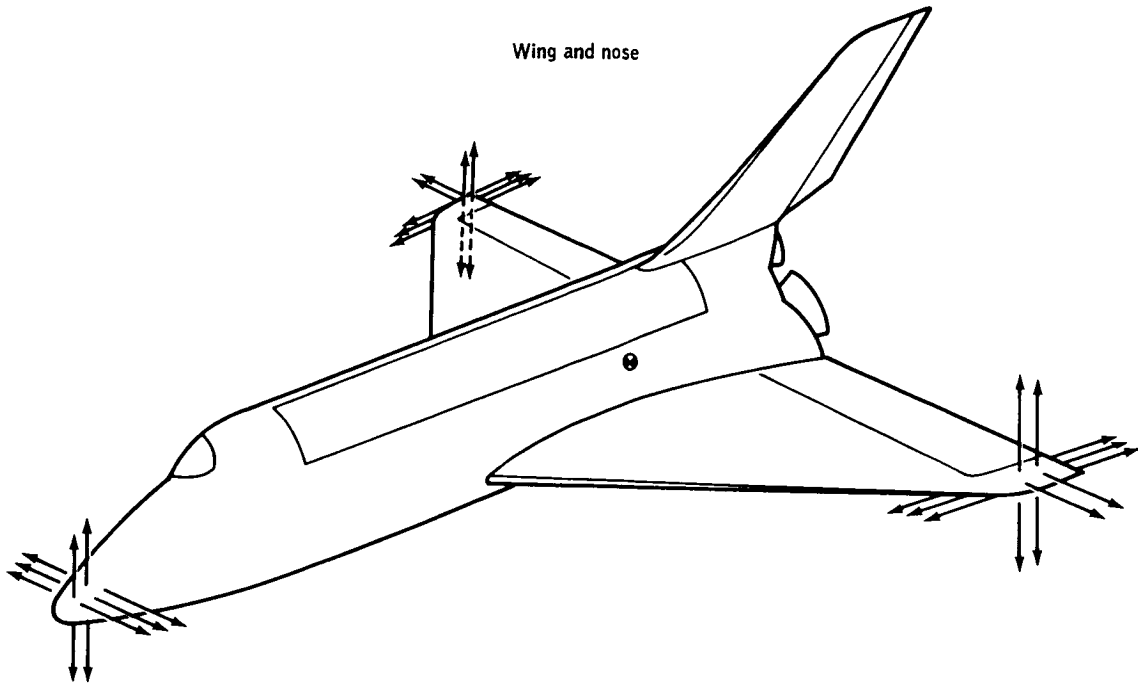


Figure 2-23. RCS Location

Table 2-V  
Minimum Angular Stability Rates

Axis	Stability Rates
Pitch	(TBC)
Yaw	(TBC)
Roll	(TBC)



## PAYLOAD CHECKOUT

Payload checkout provisions are comprised of mission specialist station CRT and keyboard, computer for payload monitoring, stored program processor, payload provided regional acquisition units (RAU's), recorders, displays and controls, and payload command decoder subunits. Figures 2-24 and 2-25 show these interfaces. The computer provides for software, data processing, command and control, data acquisition, and display capabilities required for payload functional end-to-end checkout, and status monitoring while installed in the payload bay.

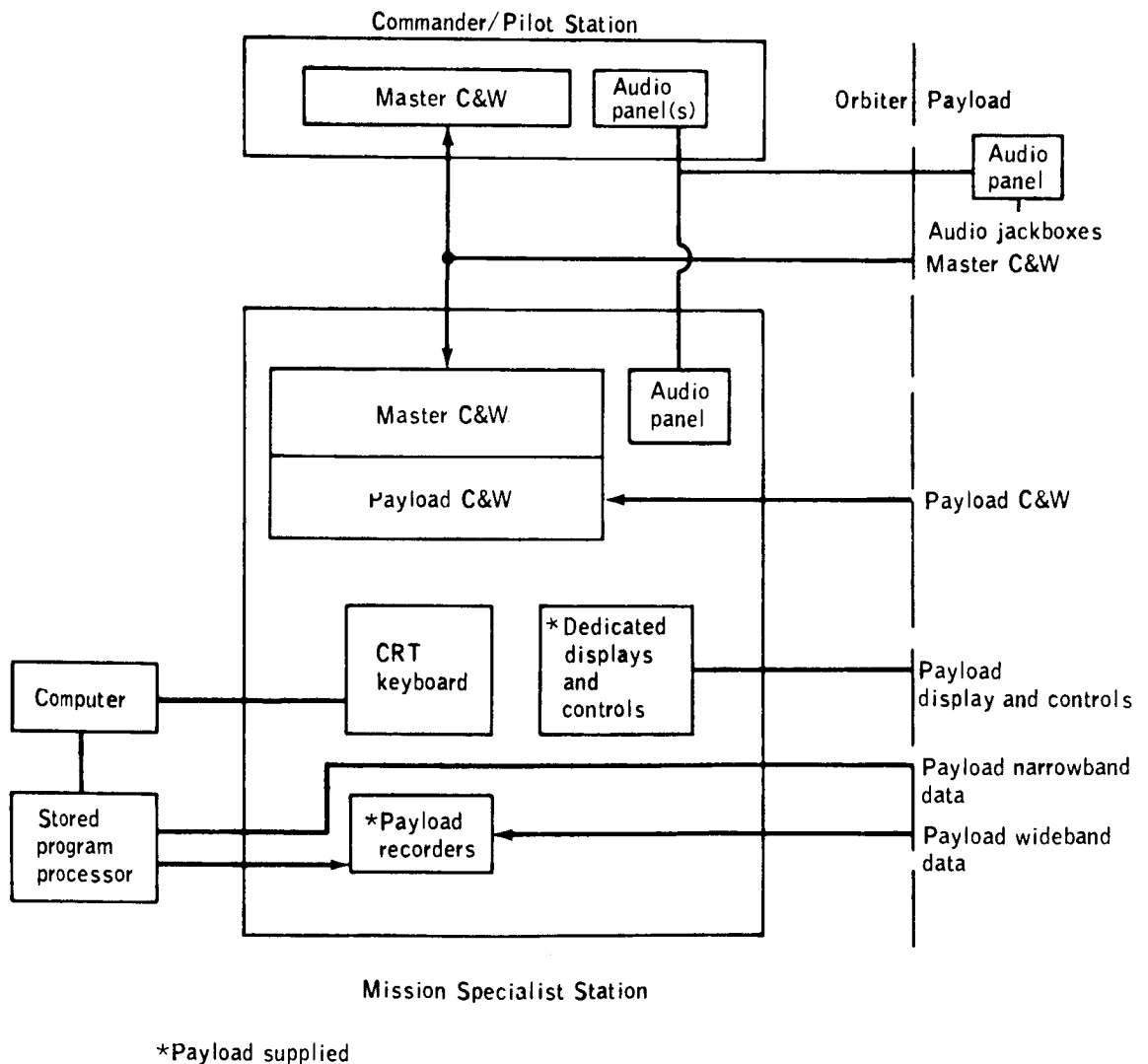


Figure 2-24. Mission Specialist Station Interfaces

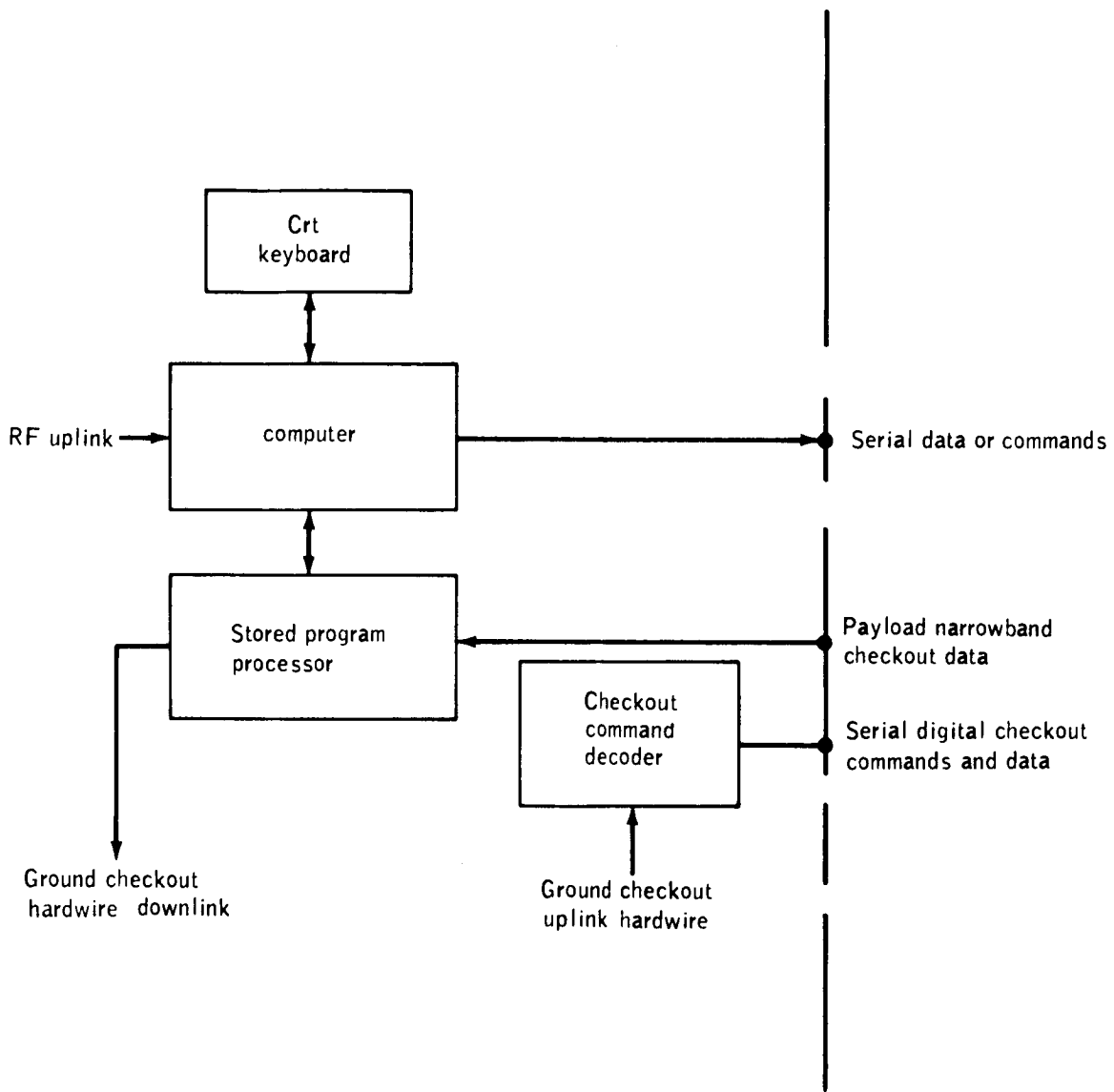


Figure 2-25. Orbiter/Payload Checkout of Interface

Detailed acceptance testing of each payload item is performed prior to installation. Checkout of the payload for prelaunch operations makes use of the ground checkout equipment and the onboard checkout command decoder for hardwired uplink commands. A hardwired PCM downlink to the ground checkout equipment is also provided for checkout data, which is interleaved with orbiter subsystem data.

The physical interfaces to the payload for inflight use are the RAU's and the payload command decoder subunits provided by the payload. This allows for the payload to be commanded from the ground via the RF link or the onboard payload monitor station through the command decoder subunit. A keyboard permits the mission specialist to communicate with the computer, and a CRT permits the display of payload checkout data.

Checkout data are collected from the payload by the payload RAU's and sent to the stored program processor (SPP). It can then be interleaved with orbiter downlink PCM, and either sent to the ground via the RF link or recorded under certain circumstance on a recorder.

Payload Regional Acquisition Unit (RAU) — The payload RAU interfaces the payload with the stored program processor (SPP). It will sample the payload data outputs on command from the SPP. The design requirements for the RAU are as follows —

- A. The RAU interface with the stored program processor utilizes party line techniques to minimize the amount of interface wiring required.
- B. The RAU accepts analog and digital signals in the quantities, and mixtures based on payload measurement requirements.
- C. The RAU samples and digitizes payload analog signals to the accuracy required by the computer and other data users.
- D. The RAU samples payload checkout data at sampling rates compatible with the computer and other user requirements.
- E. The RAU is packaged to operate during all mission phases in the same environment as the vehicle subsystems with which it interfaces.

Payload Command Decoder Subunit (PCDS) — A serial digital line is provided from the computer through the PCDS. This allows the payload to be commanded from the ground or from the mission specialist station keyboard. The PCDS provides stimuli and commands to the payloads for operation or checkout. The design requirements are as follows —

- A. Accept serial digital commands and provide verification of correct digital commands/sequences from the computer
- B. Be capable of simultaneous command/stimuli generation, i.e., employ multiple programmable function generators

- C. Providing automatic, builtin calibration means upon command, via serial digital data from the computer
- D. Be environmentally packaged for the payload environment

Hardware Interfaces — Coaxial cables and wires are provided between the payload interface and the mission specialist station (MSS). These can be used for interfacing payload provided displays, recorders, controls, et cetera, installed in the console at the MSS with payloads. Standardized interface connectors are provided on these wires. Time codes and synchronization frequencies can be made available from the orbiter central timing unit, and transmitted to the payload by these interfaces.

## COMMUNICATIONS

Figure 2-26 is a schematic diagram of the communications provisions.

Voice — The orbiter audio communications system provides voice communications for payload operations as follows —

- A. Two-way voice communications between the payload bay and ground
- B. Two-way voice communications between crew stations and the payload bay stations
- C. Radio frequency (RF) voice communications between released payloads and the orbiter
- D. EVA voice communications used onboard the orbiter or relayed to the ground. Two unique EVA channels are provided, with conference capability to (TBC) additional EVA's.

Wideband Data — A hardwired interface is provided in the payload bay for transmission of realtime or delayed wideband payload data to the ground. This link accommodates up to 256,000 bits per second (BPS) of digital data or provides wideband analog data. In either case, the payload provides the necessary equipment to insure that the payload data are compatible with the orbiter transmitter.

Digital Data — Payload PCM data from RAU's in the payload bay can be transmitted to the ground through the stored program processor and S-band transmitter. Up to 25,000 BPS of payload data can be transmitted to the ground by

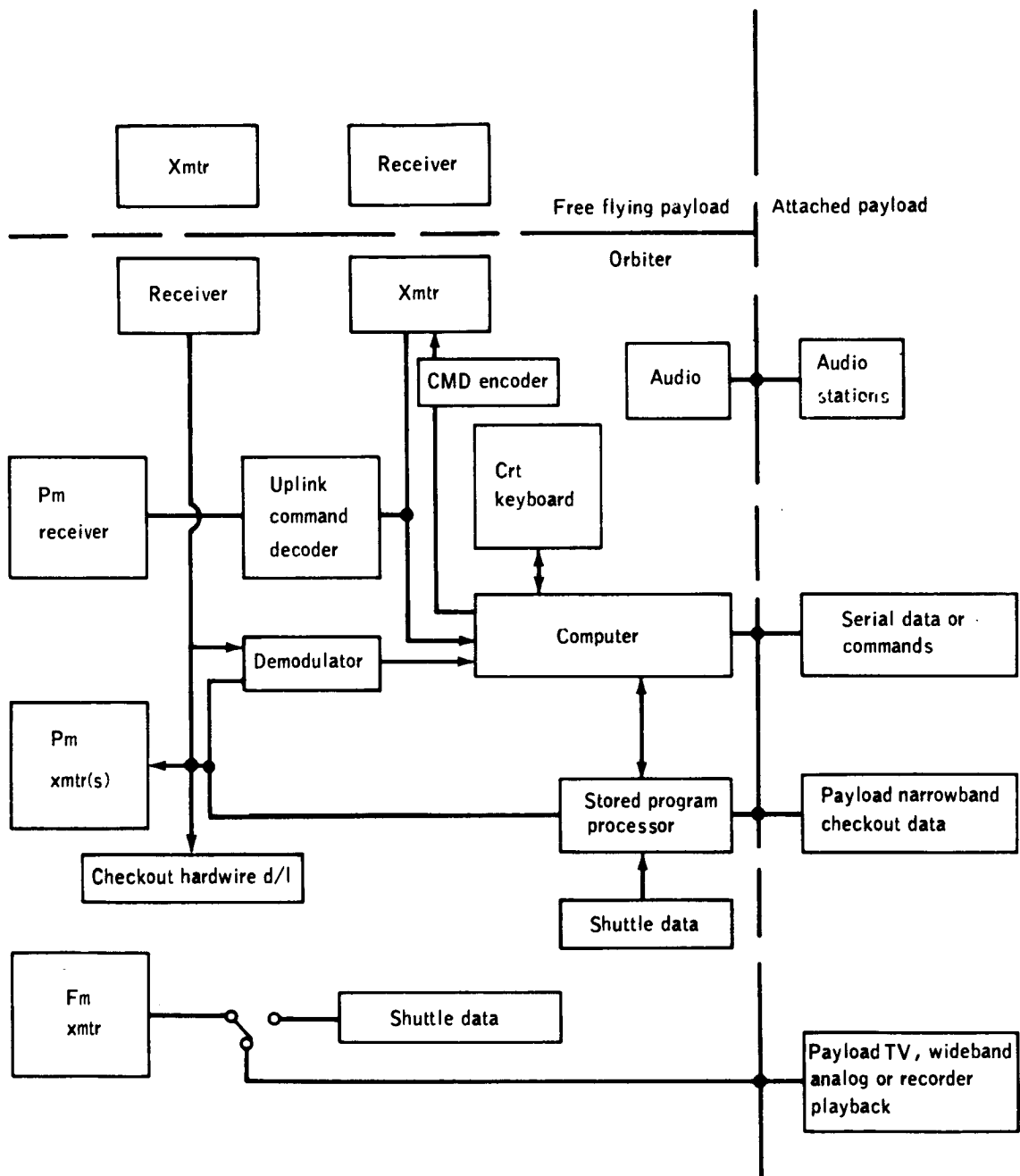


Figure 2-26. Orbiter/Payload Communications Interface

this method. Data from released payloads up to 2,000 BPS can be received by the orbiter system for relay to the ground, or for transmission to the computer used for payload monitoring.

Television (TV) — Two coaxial interfaces are provided in the payload bay for transmission of payload TV video signals to the ground, or to the video displays at the payload handler station.

Uplink Commands/CATA — Inflight uplink information for attached payloads is routed to the computer from the S-band uplink command decoder. This information is relayed to the payload via a serial digital interface to the PCDS. In addition, this information can be relayed to release payloads (up to a range of TBC miles) via RF, up to 2,000 BPS, commands originated in the orbiter can also be transmitted to the released payloads by the same means. This link includes a command confirmation capability.

## CREW SYSTEMS

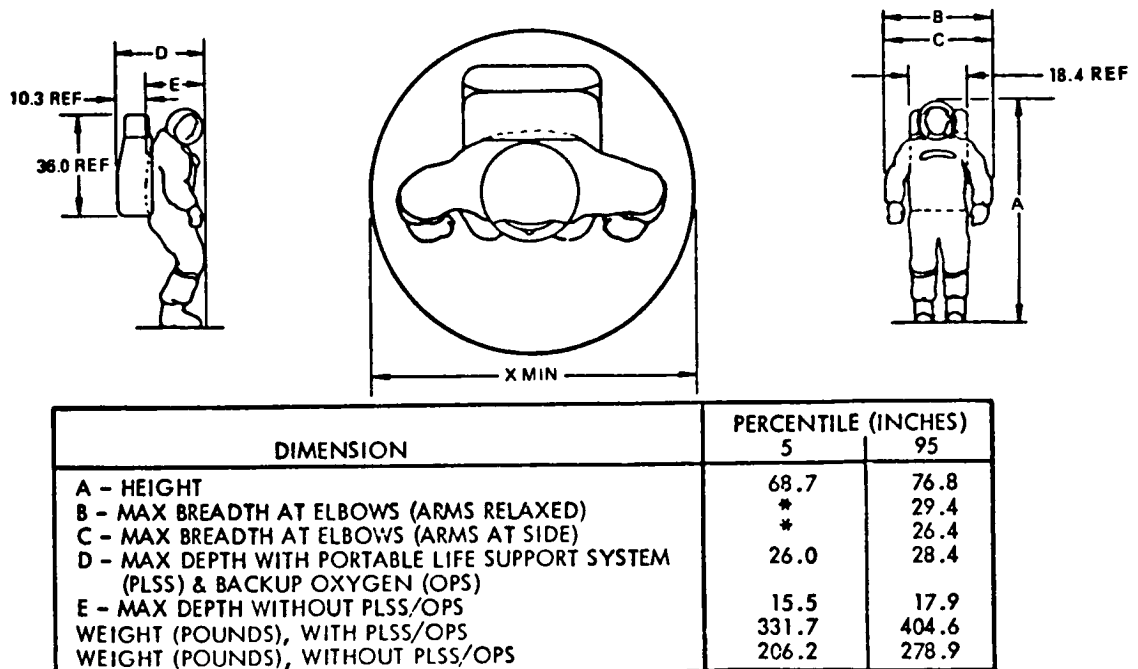
Supports and Restraints — Mobility aids are provided in the payload bay and orbiter structure. These mobility aids include strategically located handholds, tether-attachment points, and foot restraints at work areas. Similar mobility aids should be provided on payloads which require crew operations such as maintenance, inspection, deployment, or habitation.

EVA Support Equipment — The EVA capability for a minimum of two crewmen is provided by the orbiter. To support EVA, the orbiter has an airlock, EVA equipment storage and donning area, extravehicular life support system (EVLSS) recharging station, crew mobility aids, and the necessary communication circuits and monitoring systems for on-orbit operations. The EVA equipment and expendables are available, and are chargeable to the payload. This EVA equipment includes — (1) pressure garment assemblies (PGS's), (2) EVLSS's, (3) maneuvering systems, (4) tool kits, (5) restraints, and (6) portable lights. Standard tools and a torquing device are included in the tool kit. Specialized tools and tool adapters are provided by the payload.

EVA Design Considerations — The following items must be considered in payload design to ensure compatibility with the EVA crewman to obtain maximum utility from time spent in EVA.

- A. Handholds or guiderails are provided along the EVA traverse wherever possible.

- B. Foot restraints and tether-hook attach points are provided at work stations or wherever pulling, pushing, or torquing actions are required.
- C. Maximum force and torque capabilities for the restrained EVA crewmen are —
- Torque — (TBD) ft-lbs
- Force Pull — (TBD) lbs
- Force Push — (TBD) lbs
- D. Reach mobility and visibility are considered in work station design. Tools and controls must be compatible with the gloved hand.
- E. Maximum envelope dimensions of the PGA/PLSS are shown in Figure 2-27.
- F. Lighting levels are compatible with the tasks to be performed.



\* INDICATES DATA NOT AVAILABLE  
 FOR DIMENSIONS D & E 2 INCHES HAVE BEEN ADDED TO MAXIMUM CHEST OF SUITED/PRESSURIZED CREWMAN FOR PLSS CONTROL BOX TO OBTAIN ENVELOPE DIMENSIONS  
 MEASUREMENTS MADE ON A7L PGA, PRESSURIZED TO 3.75 PSIG

Figure 2-27. PGA/PLSS Dimensions

G. Sharp or dangerous objects are eliminated from the EVA route.

Payload weight which can be transferred by the crewman is dependent upon the physical configuration of the payload and the method of transfer. Payload transfers from the payload bay to an EVA work station can be accomplished by the crewman carrying the payload to the work station, or by using a transfer device such as clothesline type conveyor. To carry the payload to the work station, the crewman grasps the payload by means of handholds, or attaches the payload to the PGA or other EVA equipment by means of restraint devices.

EVA Airlock — An airlock(s) is provided by the orbiter which allows dual EVA from the orbiter. The airlock(s) provide IVA access to the payload bay with payload doors closed, as well as external to the orbiter. The EVA capability exists with or without an orbital element attached to the docking port.

Crew Compartment/Payload Bay Access — An internal access between the crew compartment and the payload bay is designed in the orbiter. This access allows shirtsleeve IVA transfer of personnel and cargo through a hatch located in the aft section of the cabin to a habitable payload module in the payload bay. Located within the pressurized volume of this interface are redundant power, C+W, data, communications, and fluid interface connectors to support habitable payloads in the payload bay.

Illumination — The orbiter has lighting systems to support orbiter/payload operations external to the orbiter, inside the payload bay, and inside the crew compartment. The external lighting system provides illumination for payload deployment, docking, and retrieval operations. Payload bay illumination is available for payload inspection, attached payload operations, payload latching, and payload release. The lighting system within the cabin illuminates the payload display and control station at levels which are consistent with the crew compartment illumination requirements.

#### ENVIRONMENTAL CONTROL/LIFE SUPPORT SYSTEM

System Capabilities — The orbiter environmental control/life support system (ECLSS) baseline is designed to accommodate a crew of four for a mission duration of 7 days. This system has the capability to accommodate up to 42 man-days without system changes. With minor changes, six additional people can be accommodated with slight increases in atmospheric dry bulb temperature, humidity, and carbon dioxide content.

Atmosphere Supply and Pressure Control — This system is designed to control and maintain automatically a two-gas, sea level equivalent atmosphere (14.7 psia,



80-percent nitrogen, 20-percent oxygen) within the orbiter cabin and habitable payload modules.

The weight of additional atmosphere storage equipment and expendables to support missions beyond 28 man-days are charged to the payload. The payload should not introduce additional oxygen or nitrogen into the habitable atmosphere.

**Active Thermal Control** — The orbiter active thermal control subsystem provides interface heat exchangers to reject payload waste heat to the orbiter heat rejection equipment. This subsystem is capable of transferring payload waste heat up to 5200 BTU/Hr during peak orbiter operations, and (TBD) BTU/Hr during on-orbit coast periods. Supplementary on-orbit heat rejection is provided by orbiter water evaporation or by payload supplied heat rejection systems. The payload is also responsible for providing the payload heat transport thermal control system and hardware to interface with the orbiter active thermal control subsystem interface heat exchanger.

**Waste Management** — All solid and liquid waste products are stored onboard for return to earth, however, an overboard liquid dump system is provided as a contingency measure. Waste water from payload experiments or operations is processed and/or stored by the payload.

#### PAYLOAD BAY ENVIRONMENT

**Acoustic** — The orbiter payload bay interior sound pressure level will not exceed 145 db.

**Vibration** — Vibration environment within the payload bay will not exceed current launch vehicle payload environments.

**Shock** — Orbiter/booster separation and orbiter landing are expected to induce short duration shock to the payloads.

**Flight Acceleration Loads** — The shuttle flight acceleration loads are given in Table 2-VI for the various flight phases. These load factors include the dynamic induced loads, and carry the signs of externally applied loads.

**Payload Bay Atmosphere** — The orbiter payload bay can be atmospheric controlled independent of other parts of the orbiter structure while on the launch pad. This provision allows the control of the temperature, humidity, atmosphere composition, and particle contamination of the payload bay by the use of launch site GSE.

Table 2-VI  
Preliminary Limit Load Factors for Payload

Condition	NX (G)		NY (G)		NZ (G)	
	Steady	Dynamic	Steady	Dynamic	Steady	Dynamic
Thrust Buildup/ Emergency Rebound	1.0	+/-1.0	—	+/- .25	—	+/- .25
Launch Release (Within 2 Sec. of Release)	1.5	+/-1.0	+/-0.25	+/-0.5	+/-0.25	+/-0.5
Lift-off Plus 5 Sec	1.5	+/-0.25	—	+/-0.25	+0.25	+/-0.25
Max Q Flt Region	2.0	+/-0.25	+/-0.5	+/-0.25	+0.8 -0.4	+/-0.25
Atmosphere Abort	2.0	+/-0.25	+/-0.5	+/-0.25	+0.8 -0.4	+/-0.25
Boost Flt (Max Acceleration Prior To Cutoff)	3.0	+/-0.25	+/-0.2	+/-0.25	+/-0.3	+/-0.25
Booster Cutoff/ Separation	1.0	+/-1.5	+/-0.2	+/-1.0	+/-0.3	+/-1.0
Orbiter Boost	3.0	+/-0.25	+/-0.2	+/-0.25	+0.6	+/-0.25
Re-entry	-1.0	—	+/-0.5	+/-0.25	-3.0	+/-0.5
Flyback	-0.2	+/-0.25	+/-1.0	+/-0.25	+/-2.5	+/-0.25
Landing/Taxiing/ Braking	-1.0	—	+/-0.5	+/-0.25	-3.0	+/-0.2

The orbiter payload bay is vented during the launch and entry phases, and operates unpressurized during the orbital phase of the mission. The pressure environment curves for the launch and entry phases are shown in Figure 2-28.

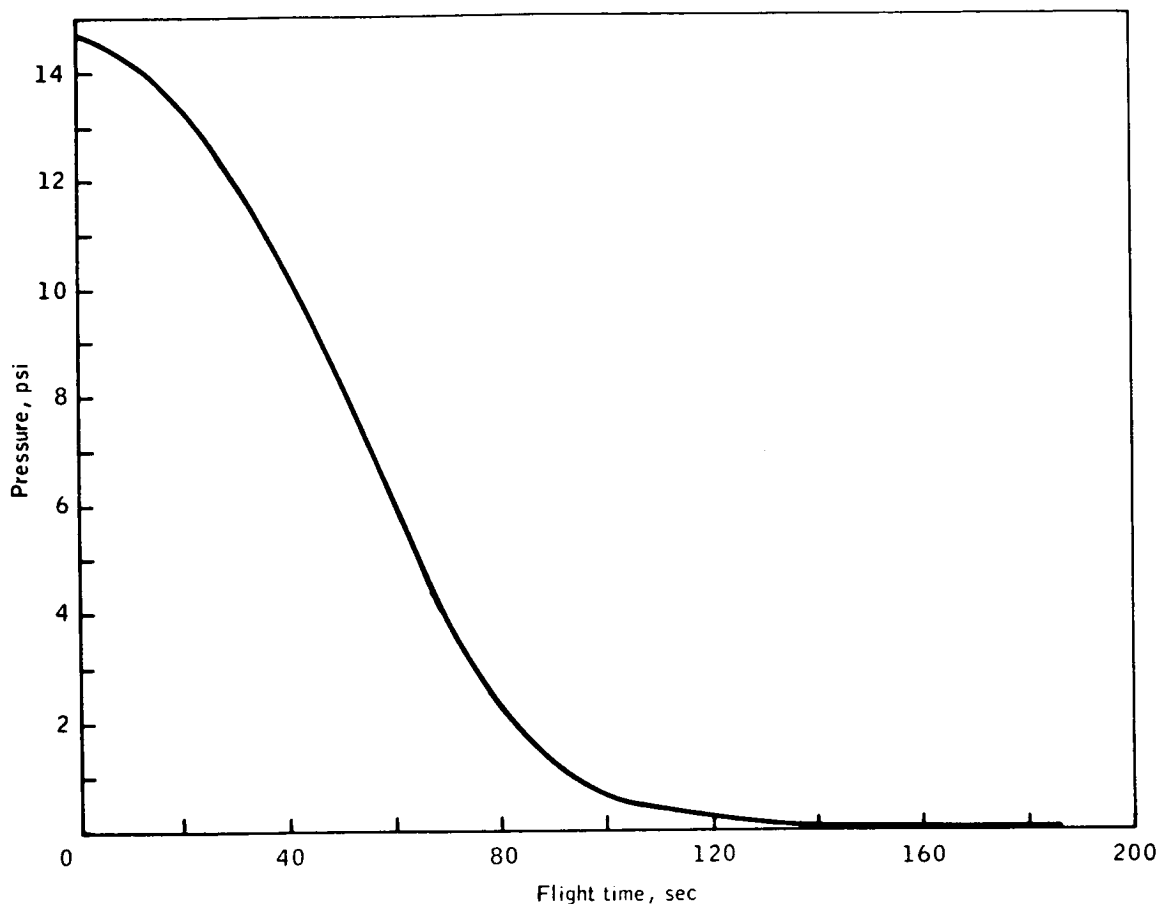


Figure 2-28. Payload Bay Internal Pressure Time History During Ascent

**Contamination** — Contamination of the payload is minimized through controlled venting, material control, and prelaunch atmospheric control. Attitude control system thrusters are designed to prevent plume impingement on the payload or payload bay.

**Thermal Environment and Control** — The determination of payload temperature and temperature environments which the payload will actually experience in the payload bay requires knowledge of the specific mission environment from boost through entry, the type of thermal control provided by the shuttle vehicle and the payload, and the payload bay and payload thermal characteristics. To obtain this information requires detailed knowledge of the actual shuttle and payload design, as well as the specific inflight orientations which probably will vary for each different mission objective. As shuttle payload bay and payload thermal design criteria is currently envisioned, the following design requirements have been imposed on the shuttle vehicle thermal design.

The internal wall temperature limits for the payload bay, not considering payload heat addition or removal shall remain within the ranges noted in the following table —

<u>Condition</u>	<u>Minimum (F)</u>	<u>Maximum (F)</u>
Prelaunch	+40	+120
Launch	+40	+150
On-Orbit (Door-Closed)	-100	+150
Entry and Post Landing	-100	+200

As an on-orbit thermal control point-design for sizing the nominal payload passive thermal control provided by the orbiter, the payload bay is designed to limit the net heat leak into or out of a 100-degree fahrenheit constant temperature payload to 3 BTU/Hr/square foot, with the payload doors closed under worst-cast orbital orientations.

Provisions are incorporated in the payload bay-way design for attachment and removal of passive thermal control in modular form to meet variable payload thermal control requirements.

The temperature limits specified for the prelaunch, launch, and entry phases provide a design environment interface between the payload and payload bay, which represents conservative payload bay-wall environment temperatures for a passive payload. Because of the variable nature of the on-orbit payload bay thermal control requirements, caused by variations in the orbit thermal environment and payload thermal requirements, flexibility in meeting these variations is provided by removal and placement of different passive insulation systems as required. An on-orbit point design requirement provides for nominal payload bay passive thermal control in the payload bay design.

If the payload bay cannot be passively controlled, provisions for limited active thermal control of the payload is available from the shuttle orbiter. Active payload thermal control is supplied by the orbiter active fluid loop system through a heat exchanger in the orbiter to support the payload in the payload bay. The heat transfer capacity for payloads equipment is —

- A. Peak capacity of 5200 BTU/Hr during peak orbiter operations

## B. Peak capacity of (TBD) BTU/Hr during on-orbit coast periods

Since a minimum energy allowance of 50 kWh is provided by the orbiter electrical power system for payload support, a portion of this power can be utilized for active heater thermal control, depending upon other payload electrical power requirements.

Radiation — Radioactive sources on the orbiter are controlled to reduce stray signal sources to experiments or payloads carried by the orbiter. Payload supplied radioactive sources are approved through the Orbiter Integration Center (MSC) to meet all flight and safety requirements.

## SAFETY, RELIABILITY, AND QUALITY ASSURANCE

### SHUTTLE CAPABILITIES

Aborts — The shuttle is designed to provide safe mission termination capability for all flight regimes. Safe mission termination includes the intact return of payloads to earth.

Crew and Passenger Egress — Emergency egress capability for the crew and passengers is provided for prelaunch and postlanding operations.

Caution and Warning — The shuttle provides a caution and warning system for processing and displaying critical payload data. See Section 2.30400 for a description of the caution and warning system.

Payload Control — The shuttle provides a limited hardware and RF control capability to provide corrective means to circumvent catastrophic events from occurring, and for activation and deactivation of payload systems. See Sections 2.30700 and 2.30800 for more details.

Dumps and Vents — The capability to dump liquids and vent gases is provided. Interconnects to the dump and venting systems are available to safely remove liquids and gases from the payload bay, if required.

Purge — A nitrogen purge capability is provided for inerting the payload bay prior to launch.

### PAYLOAD

Purpose and Scope — The first intent of this section is to define minimum safety, reliability, and quality assurance requirements to be invoked on payload

suppliers. These requirements consider primarily the safety, reliability, and quality assurance of payload hazards, the normal operation or failure of which could cause hazards to personnel, or damage to the shuttle system, related facilities, or other payload elements. Second, the compatibility of the payload with the shuttle interfaces is also a concern.

General Requirements — The payload supplier is responsible for the following safety, reliability, and quality assurance activities —

- A. The determination of the hazardous aspects of his payload and the implementation of required corrective measures.
- B. Assurance of the compatibility of his payload with the shuttle interfaces.
- C. Identification to NASA of the unresolved residual hazards and interface incompatibilities prior to NASA approval of his payload.
- D. The on-orbit functional reliability, quality, and safety of his payload.

### PART 3

#### SUPPLEMENT

Part 3 supplements the accommodations document with: (1) data of a more tentative nature that has not been incorporated in the document and (2) other shuttle-related information of interest to sortie users.

- SPACE SHUTTLE MISSION PAYLOAD - THE TOTAL ONBOARD PAYLOAD CONTAINED WITHIN THE SPACE SHUTTLE PAYLOAD BAY OR CREW CABIN DURING A SINGLE MISSION AND INCLUDING ON-ORBIT OPERATIONS WITH EXISTING SATELLITES. THE LAUNCH WEIGHT CHARGABLE AGAINST THE PAYLOAD ALLOTMENT INCLUDES THE PAYLOAD ITSELF, ADDITIONAL CREW AND PROVISIONS, ADDITIONAL ORBITAL MANEUVERING SYSTEM KITS (IF REQUIRED), ET CETERA
- PAYLOAD - ANY INSTRUMENT, SENSOR, OR EXPERIMENT PACKAGE OR PACKAGES CONTAINED IN OR ON A PAYLOAD CARRIER OR CARRIERS, AS A CARRYON PACKAGE INCLUDING SUPPORT OR AUXILLARY EQUIPMENT

Figure 2-29. Space Shuttle Payload Definition

#### MISSION DESIGN AND TRAJECTORY ANALYSIS

##### SPACE SHUTTLE PERFORMANCE CONSIDERATIONS

The design performance requirements of the space shuttle are given in terms of three reference missions:

- Delivery of a 65,000-pound payload to a 28.5° inclination with enough orbital maneuvering system (OMS) propellant to provide 950-fps  $\Delta V$  after insertion into a 50- by 100-nautical-mile orbit and main tank jettison. (For the current range of space shuttle weights, this mission requirement is the most severe of the three reference missions and therefore sizes the spacecraft.)
- Delivery of a 40,000-pound payload to a 90° inclination, 50- by 100-nautical-mile orbit with 500 fps of OMS propellant on board.
- Delivery of a 25,000-pound payload to a 55° inclination, 270-nautical-mile circular orbit with 1500 fps of OMS propellant on board.

The OMS tankage requirement is that the orbiter have sufficient integral tankage for 950 fps of OMS propellant with a 65,000-pound payload on board (i.e., to perform mission 1) with enough additional plug-in tanks to bring the total OMS capacity to 2500 fps. These plug-in tanks are to be carried in the payload bay.

The current design approach is for two sets of tanks integrally mounted (one on each side of the bay) having a total capacity of 950 fps with a 65,000-pound payload. As many as three more sets of these tanks, with plug-in adaptations, can be put in the payload bay to provide the required "2500-fps" capacity. Each of the three plug-in tank sets, when empty, adds 1200 pounds to the inert weight of the orbiter for a total weight increase of 3600 pounds with all three tank sets installed.

The profiles are based on integral tanks that hold a total of 23,500 pounds of usable OMS propellant when they are full. Each add-on set gives an additional 11,750 pounds of OMS capacity, with a maximum useful OMS loading of 58,750 pounds when all three extra tank sets are aboard.

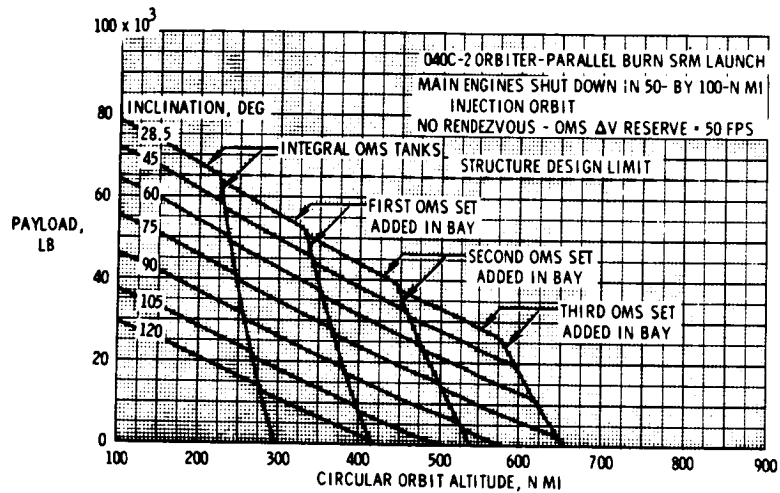
## CIRCULAR ORBITS

These figures give payload as a function of circular orbit altitude. There is a 50-fps OMS  $\Delta V$  reserve. For a rendezvous case, 120-fps of OMS  $\Delta V$  should be held back for rendezvous and reserve. In the plot on the left, insertion is always into a 50- by 100-nautical-mile orbit. Any additional altitude is achieved by the OMS alone. All performance calculations are based upon the entire payload being carried throughout all of the  $\Delta V$  maneuvers. This would allow the vehicle to deorbit in the event that the payload, for any reason, could not be jettisoned. It would also be the case if one payload were delivered to orbit and another picked up for return to earth. For these figures, payload is traded directly for OMS propellant until the OMS tanks are full.

Figure 2-30 at the bottom gives the circular orbit altitude capability of the space shuttle if the main orbiter engines are allowed to burn past the nominal 50- by 100-nautical-mile injection orbit cut-off point and can be used to insert directly into a 50 by h nautical-mile elliptical orbit where appropriate. The main engines cannot be restarted, so they are never used for circularization or retro-fire. The performance is based on the assumption that the external (main) propellant tank is always jettisoned before any OMS propellant is used for  $\Delta V$ . The OMS is not used any time in the launch phase; that is, prior to the space shuttle reaching the 50- by 100-nautical-mile injection orbit. The total injected weight on any given inclination is a constant and represents the maximum capability of the space shuttle to that inclination. The variation in payload between altitudes is due to trading payload for OMS propellant.



## PAYLOAD TO CIRCULAR ORBITS - WITHOUT RENDEZVOUS



## DIRECT INJECTION TO 50 BY h N MI WITH MAIN ENGINES

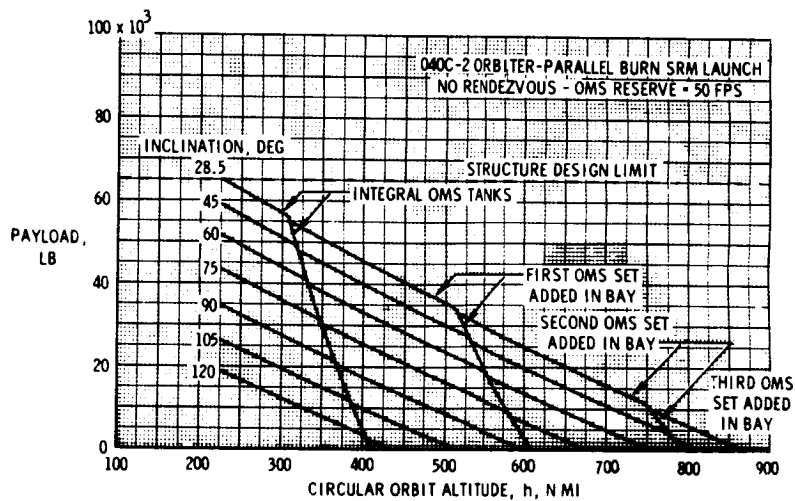


Figure 2-30. Space Shuttle

## ELLIPTICAL ORBITS

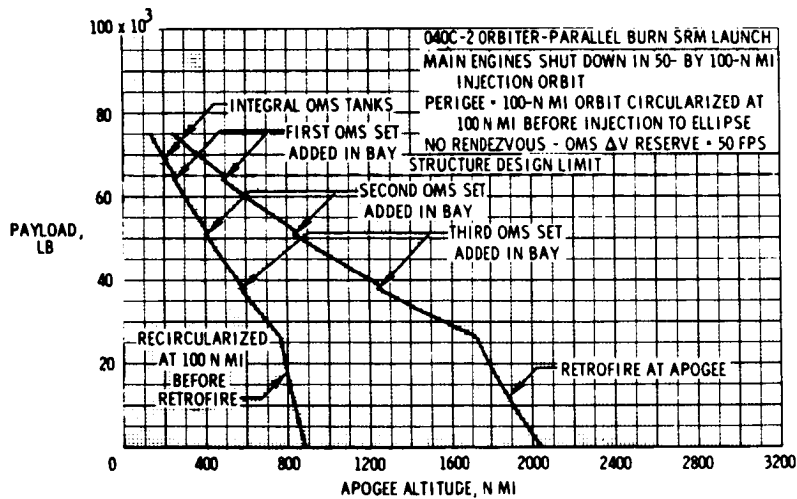
Elliptical orbits and circular orbits for the space shuttle have no simple one-to-one correspondence as far as performance is concerned. This is because entry  $\Delta V$  required for a highly elliptical orbit may vary from a few hundred feet per second to achieve entry at perigee to several thousand feet per second if the entry interface is to be under the elliptical orbit apogee. These figures show the apogee altitude as a function of payload that can be reached with the space shuttle for a 100-nautical-mile perigee.

The figure on top is for an easterly launch ( $28.5^\circ$  inclination) and the figure on the bottom is for a launch to a polar orbit ( $90^\circ$  inclination). These data are based on the assumption that the main engines are shut down in the nominal 50- by 100-nautical-mile injection orbit. The disposable tanks are then jettisoned and the orbit raised to 100 by 100 nautical miles with the OMS. After this is done, the OMS is then used again to raise the apogee. The upper curve assumes a direct retrofire at apogee with entry coming very near perigee. This can be done when no specific requirement exists on the positioning of the apsides of the ellipse. In that case, the orientation can be selected to allow the proper apsides position for direct entry from apogee. The bottom curve is for cases in which the space shuttle must recircularize at 100 nautical miles before retrofiring. This would be the case if a particular apogee position were required for the payload that resulted in the worst possible alignment of the apogee and the entry interface position, or if some factor such as entry heating limitation made direct entry from the higher ellipse impossible.

With the space shuttle launched into a high ellipse, a payload satellite could be placed into a circular orbit at apogee altitude with a single burn of a third stage. This would allow the use of a single, simple propulsion stage on the payload. A stage of this type may be simpler and cheaper than the multiple-start space propulsion stages.

The mission planner should remain aware that direct entry from the highest orbits which the space shuttle can attain can result in relative entry speeds from 1000 to 2000 fps higher than the nominal design entry conditions. Such entries must have various additional entry angle and range constraints imposed to ensure safe entry. These constraints will depend upon the final design and are not yet well defined. In general, planning for missions requiring direct entry from the higher altitudes of space shuttle capability should be coordinated with the MSC Space Shuttle Program Office to ensure that such entry constraints are not violated.

## PAYLOAD TO ELLIPTICAL ORBIT - 28.5° INCLINATION



## PAYLOAD TO ELLIPTICAL ORBIT - 90° INCLINATION

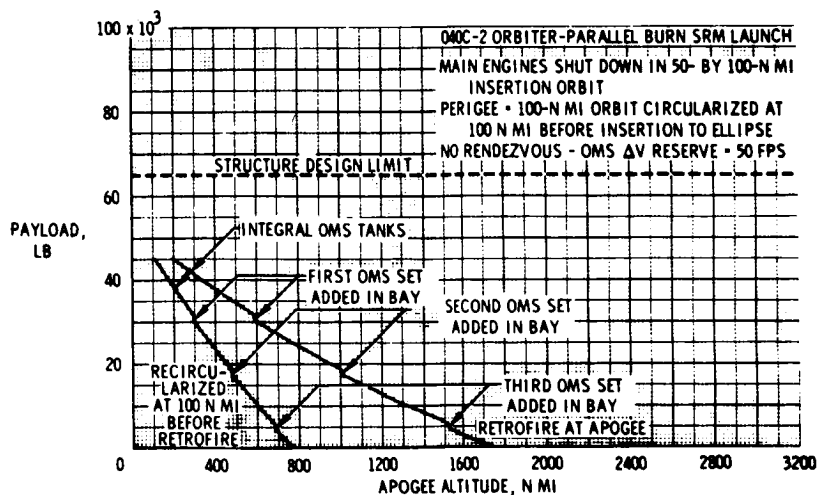


Figure 2-31. Space Shuttle

## KSC AZIMUTH SPAN

The current space shuttle configuration requires solid rocket motors (SRM's) during the launch phase. These motors are jettisoned soon after lift-off and impact about 200 nautical miles downrange. Consideration of the range safety aspects for the SRM impact and the possibility of overflights of inhabited land masses by the booster and orbiter during the launch phase indicate that certain azimuths may be restricted; hence, certain inclinations may be difficult to attain without resorting to "doglegging" launch trajectories (performance cost) or flying from the Western Test Range (WTR). The plot shows a span of practical azimuths that can be flown from KSC. The southern limit of approximately 120° azimuth is set by SRM impact near the West Indies island chain and, in

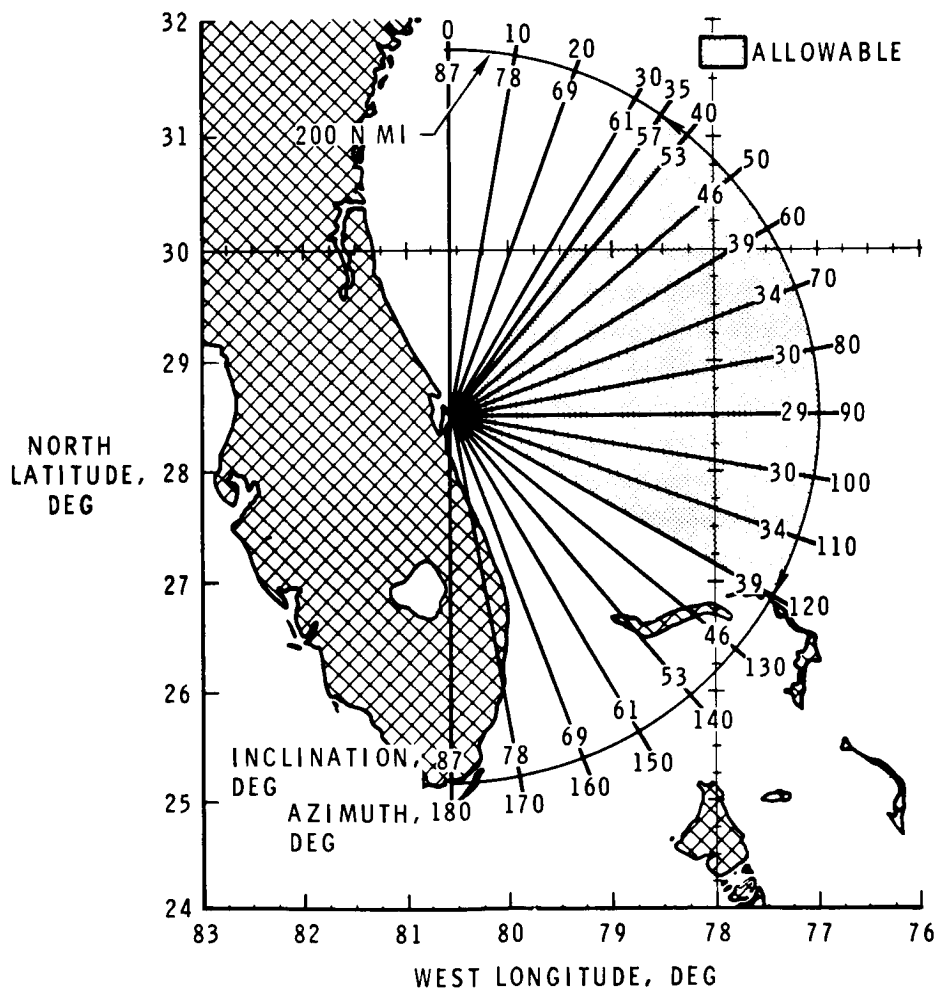


Figure 2-32. Practical Launch Azimuth Span From KSC

some cases, by the water depth, which may be too shallow for cushioning the impact of the recoverable SRM casings. The northern boundary of approximately 35° azimuth may be set by overflights of Cape Hatteras and Newfoundland.

### WTR AZIMUTH SPAN

Space shuttle missions to inclinations greater than approximately 55° or 60° may have to be launched from the WTR in a southerly or westerly direction only. As shown on the plot, any retrograde inclination ( $i > 90^\circ$ ) can be attained (at a significant performance cost). The azimuth limits of approximately 140° to the south and 313° to the north are dictated by SRM impact.

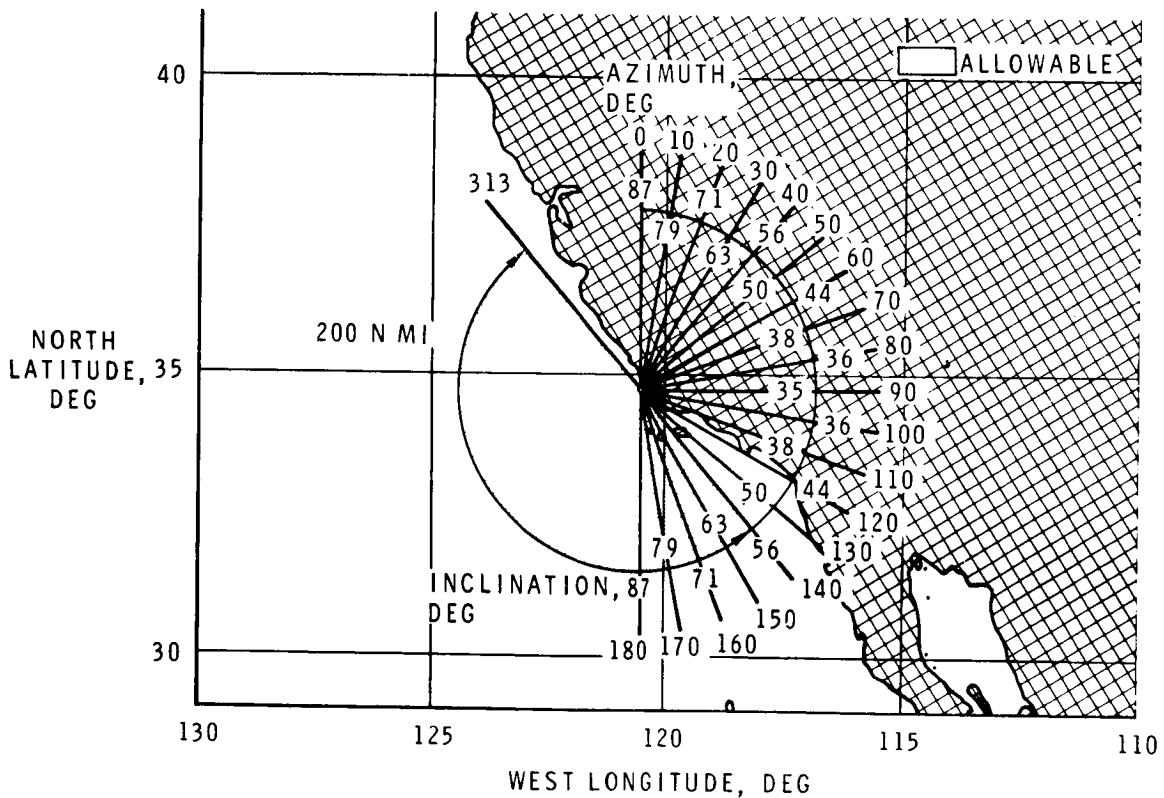


Figure 2-33. Practical Launch Azimuth Span From WTR

BASELINE INTERFACE  
ACCOMMODATIONS FOR PAYLOADS

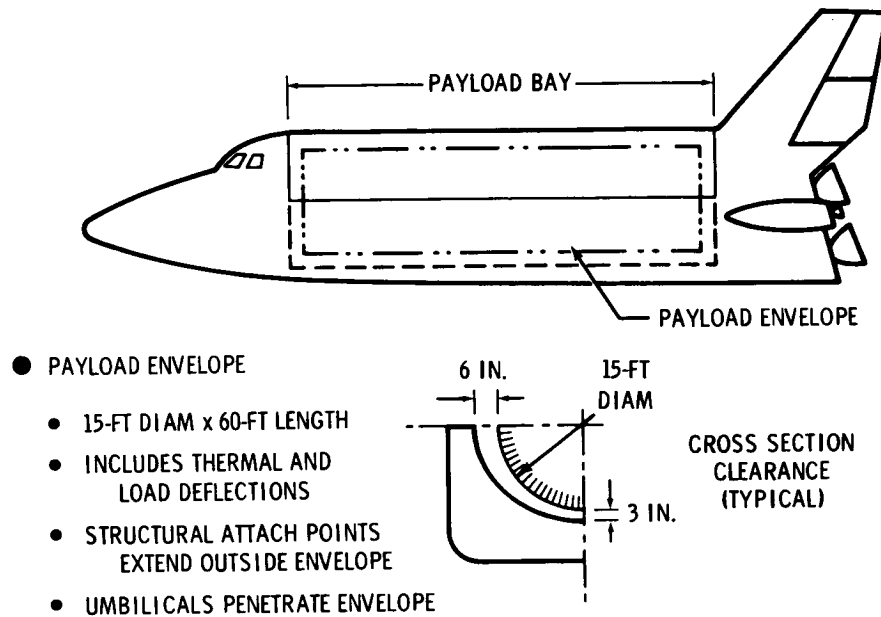


Figure 2-34. Payload Bay Envelope

- PAYLOAD BAY CLEAR VOLUME: 15-FOOT DIAMETER AND 60-FOOT LENGTH
- MANIPULATOR TO ASSIST PAYLOAD HANDLING - OTHER MECHANISMS MAY ALSO BE USED
- DOCKING MECHANISMS WITH 1-METER CLEAR TRANSFER PASSAGEWAY
- ORBITER DESIGNED TO LAND 40 000-POUND PAYLOAD - LARGER PAYLOADS WITH REDUCED SAFETY FACTORS
- MULTIPLE STANDARDIZED ATTACHMENT POINTS TO SUPPORT PAYLOADS
- PAYLOAD BAY DOORS EXPOSE ENTIRE LENGTH AND WIDTH OF PAYLOAD BAY WITH 180° UNOBSTRUCTED LATERAL FIELD OF VIEW

Figure 2-35. Structural/Mechanical Interfaces

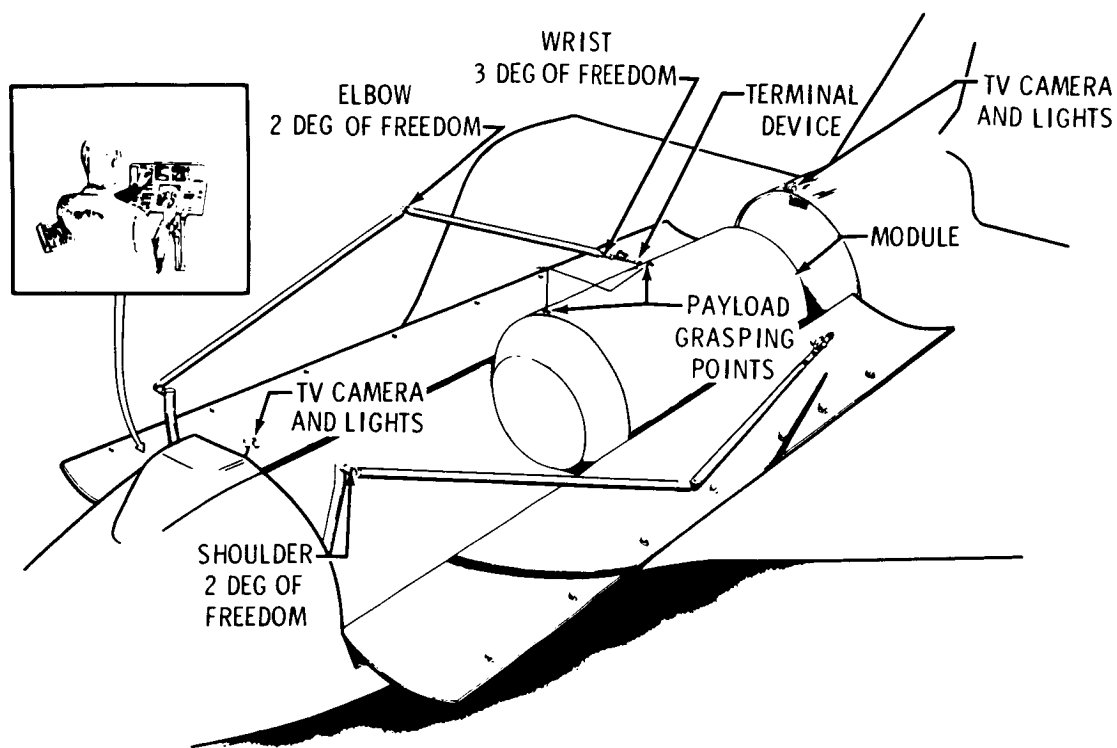


Figure 2-36. Typical Remote Manipulator System

● BASELINE ANGULAR STABILITY RATES OF MAIN THRUSTER SIZE FOR REENTRY

<u>AXIS</u>	<u>RATE</u>
PITCH	0.011 DEG/SEC
YAW	.066 DEG/SEC
ROLL	.100 DEG/SEC

● PROPELLANT CONSUMPTION PER DAY TO MAINTAIN ATTITUDE HOLD

<u>SYSTEM</u>	<u>DEADBAND</u>	<u>RATE</u>	<u>PROPELLANT USAGE*</u>
MAIN THRUSTERS	0.5 DEG	0.10 DEG/SEC	307 LB/DAY
	.1 DEG	.10 DEG/SEC	1535 LB/DAY

\*MAY BE PARTIALLY CHARGED TO PAYLOADS

Figure 2-37. Attitude Control

- GENERAL PURPOSE - BASELINE WITH ORBITER
  - SINGLE PAYLOAD MANAGEMENT STATION
  - DEDICATED DIGITAL COMPUTATION
  - CAUTION AND WARNING, TOP DECK MONITORING AND CONTROL
  - COMMUNICATION AND DATA
  - CHECKOUT STIMULI AND RESPONSE ASSESSMENT
  - POWER
  - PAYLOAD DEPLOYMENT AND RECOVERY
  - DATA RECORDING
- SPECIFIC PAYLOAD UNIQUE
  - SOFTWARE
  - DEDICATED STATIONS (MODULAR KITS)
  - SPECIAL RECORDERS
  - INTERFACE UNITS (IF REQUIRED)
  - PAYLOAD BAY TELEVISION

Figure 2-38. Payload Avionics Approach and Philosophy

- TWO-WAY VOICE INTERCOM (SPACE SHUTTLE-PAYLOAD-EVA)
- CONFERENCE VOICE (GROUND-SPACE SHUTTLE-PAYLOAD, ATTACHED OR DETACHED)
- LOW TO MEDIUM DIGITAL DATA INTERFACE (SPACE SHUTTLE-PAYLOAD-GROUND)
  - 25 KBPS DEDICATED
  - 256 KBPS MAXIMUM
- WIDEBAND ANALOG DATA INTERFACE (SPACE SHUTTLE-PAYLOAD-GROUND)
- LOW DIGITAL RF INTERFACE (SPACE SHUTTLE-RELEASED PAYLOAD)
  - 2 KBPS
- COLOR TELEVISION (SPACE SHUTTLE-PAYLOAD-GROUND)
- CAUTION AND WARNING (HARDWIRE SPACE SHUTTLE-PAYLOAD)
- PAYLOAD DATA PROCESSING (INCLUDING COMMAND, CONTROL, AND MONITOR)
  - 10 000 32-BIT WORDS RESERVED FOR PAYLOADS
- SPACE ALLOCATION IN SPACE SHUTTLE FOR DEDICATED DISPLAYS AND CONTROLS PROVIDED BY PAYLOAD
- PAYLOAD GN&C INITIALIZATION DATA (INCLUDING PASSIVE PAYLOAD RENDEZVOUS/DOCKING SENSORS TO ORBITER GN&C COMPUTER INTERFACE)

Figure 2-39. Avionics



- LAUNCH AND ENTRY
  - 3400 BTU/HR AVERAGE
  - 5200 BTU/HR PEAK
- ON-ORBIT COAST
  - 13 400 BTU/HR PEAK\*
  - ADDITIONAL HEAT REMOVAL CAPABILITY  
AVAILABLE BY WATER BOILING

\* NOTE: VERY CONFIGURATION DEPENDENT, COULD BE GREATER

Figure 2-40. Payload Active Thermal Control

● INTERNAL PAYLOAD BAY WALL TEMPERATURE LIMITS

<u>CONDITION</u>	<u>MINIMUM</u>	<u>MAXIMUM</u>
PRELAUNCH*	+ 40° F	+120° F
LAUNCH	+ 40° F	+150° F
ON ORBIT	-100° F	+150° F
ENTRY AND POSTLANDING*	-100° F	+200° F

- ACOUSTIC
  - OVERALL SOUND PRESSURE LEVEL LESS THAN 145 DECIBELS
- ADDITIONAL THERMAL AND ACOUSTIC PROTECTION CAN BE PROVIDED AND THE WEIGHT CAN BE CHARGED TO THE PAYLOAD
- PRESSURE
  - VENTED TO AMBIENT, UNPRESSURIZED DURING ORBITAL OPERATIONS

\* GSE AVAILABLE FOR CONTROLLED ENVIRONMENT

Figure 2-41. Payload Bay Environment

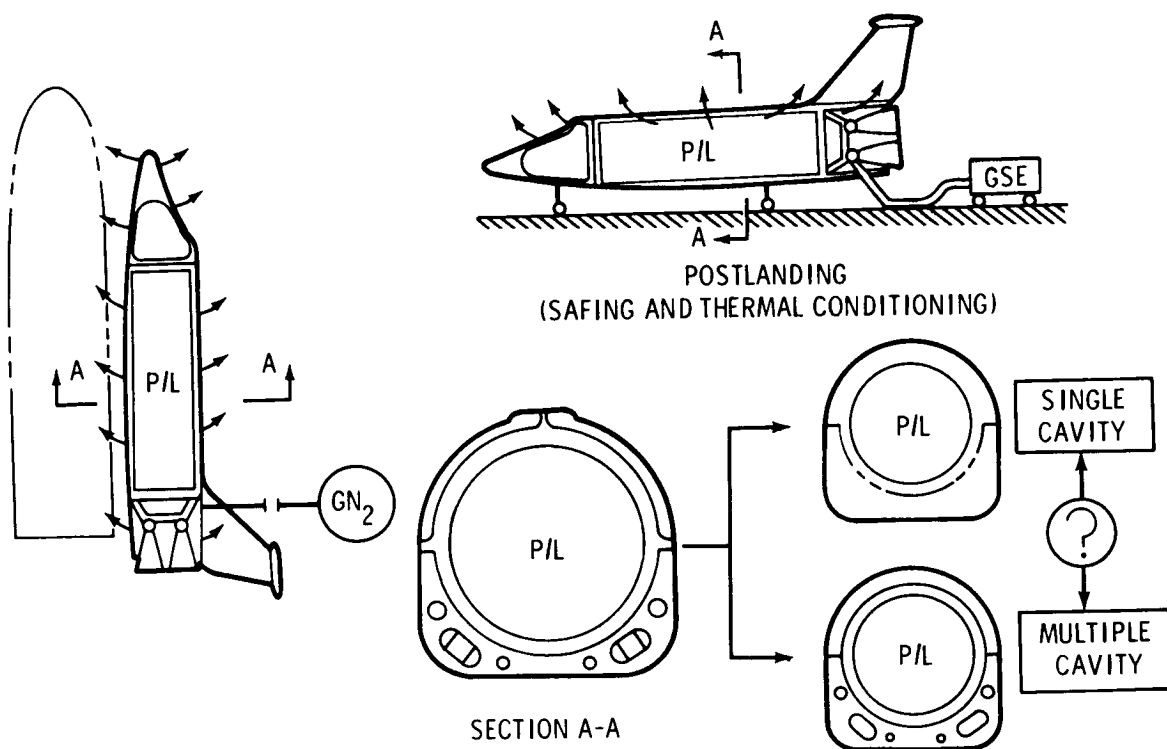


Figure 2-42. Purging/Safing

<u>CONDITION</u>	<u>X</u>	<u>Y</u>	<u>Z</u>
LIFT-OFF	$1.5 \pm 1.0$	$0.25 \pm 0.5$	$0.25 \pm 0.5$
MAXIMUM BOOST	$3.0 \pm 0.25$	$0.2 \pm 0.25$	$0.3 \pm 0.25$
ENTRY	-1.0	$0.5 \pm 0.25$	$-3.0 \pm 0.5$
LANDING	-1.0	$0.5 \pm 0.25$	$-3.0 \pm 0.5$

Figure 2-43. Payload Design Limit Accelerations, G

<u>COMPONENT</u>	<u>SOURCE</u>	<u>REMARK *</u>
H <sub>2</sub> O	FUEL CELLS	ALL-UP AVIONICS, CAN HOLD FOR 24 HOURS
	ECLSS BOILER	RADIATORS LOOKING AT SUN
	CABIN LEAKAGE	
O <sub>2</sub> , N <sub>2</sub> , CO <sub>2</sub>	CABIN LEAKAGE	
N <sub>2</sub> H <sub>4</sub>	RCS FIRING	0.5° DEADBAND
URINE	WASTE MANAGEMENT	CAN HOLD FOR 24 HOURS
FECAL VAPORS	WASTE MANAGEMENT	CAN HOLD FOR 24 HOURS
*UNDER REVIEW		

Figure 2-44. Contamination

- ECLSS
  - ATMOSPHERIC GASES AND TANKAGE
  - LIOH CANISTERS
- CREW SUPPORT EQUIPMENT
  - FOOD
  - CLOTHING
  - PERSONAL HYGIENE
  - EQUIPMENT STORAGE
- ELECTRICAL POWER
  - REACTANTS
  - TANKAGE
- PROPULSION
  - OMS  $\Delta V$  FOR ORBITAL DECAY IN LOWER ALTITUDES
  - RCS PROPELLANTS FOR ATTITUDE CONTROL

Figure 2-45. Additions to Achieve 30-Day Mission Capability

## OPERATIONS AND MISSION CONTROL

### SPACE SHUTTLE ORBITAL OPERATIONS

The exact time of disposal of the external tank will continue to be a mission design variable. The drop tanks must be retained as long as needed (i.e., for proper orbit insertion conditions); however, disposal time must also be consistent with controlled water impact.

Fundamentally, the rest of the activities shown in the figure are "standard operations procedures."

- AFTER ACHIEVING PROPER ORBIT CONDITIONS, THE 'DROP TANK' WILL BE SEPARATED (SPECIAL PROVISIONS WILL BE MADE TO CONTROL THE TANK DEORBIT PARAMETERS)
- AFTER EXTERNAL TANK DISPOSAL, THE FLIGHT CREW WILL:
  - CHECK THE ORBITER SUBSYSTEM AND NAVIGATION PARAMETERS
  - MAKE PREPARATIONS FOR RENDEZVOUS - EITHER WITH A TARGET VEHICLE OR PREPLANNED ORBIT CONDITIONS
- MEANWHILE, THE MISSION SPECIALIST AND PAYLOAD SPECIALIST WILL CONFIGURE AND CHECK OUT THE MISSION PAYLOAD
- THE REST OF THE ORBIT PHASE WILL CONSIST OF:
  - PAYLOAD OPERATIONS
  - SHUTTLE SUBSYSTEM MONITOR AND OPERATIONS
  - ACTIVITY SCHEDULING
  - ORBITER AND PAYLOAD MALFUNCTION DETECTION, EVENT LOGGING, AND, IF POSSIBLE, MALFUNCTION CORRECTION
  - CREW HABITABILITY (EAT, SLEEP, ETC)
- THE ORBITER ORBIT DETERMINATION AND MANEUVER PLANNING WILL BE ACCOMPLISHED BY THE ORBITER CREW
- THE GROUND WILL BE ABLE TO ASSIST THE ORBITER CREW AS REQUIRED

Figure 2-46. Space Shuttle Orbital Operations

### SPACE SHUTTLE ENTRY

Provisions will be made for automatic control during entry, but the actual mode used (i.e., automatic or manual) will be at the discretion of the space shuttle commander.

Consideration has been given to early mission termination (aborts). Depending upon the nature of the problem, these landings may occur at the nominal

end-of-mission landing site or at two or three preselected alternates. Position and velocity data will be kept current, as well as entry criteria, so that entry parameters for these contingency entries can be computed quickly. The nominal end-of-mission parameters will be computed premission and verified or updated early in the last day of the mission.

"Early in the last day" needs to be emphasized because, depending upon the criteria established for the variables in the computations, an on-orbit wait of several hours may result; (i.e., it may require several orbits to acquire adequate tracking data and/or to achieve orbit conditions compatible with space shuttle performance and landing site location).

The required operations are standard operations procedures as listed in the figure.

- ENTRY WILL BE AUTOMATIC, WITH MANUAL INTERVENTION IF REQUIRED
- CONTINGENCY ENTRY PARAMETERS WILL BE KEPT CURRENT AT ALL TIMES
- PLANNED (END-OF-MISSION) REENTRY PARAMETERS MUST BE ESTABLISHED PREMISSION AND VERIFIED EARLY IN THE LAST DAY OF THE MISSION
- THINGS THAT MAKE EARLY PLANNING ESSENTIAL ARE:
  - LANDING SITE SELECTION
  - GROUND-TRACKING REQUIREMENTS/CAPABILITIES
  - CROSS-RANGE REQUIREMENTS/CAPABILITIES
  - ANY SPECIAL PAYLOAD REQUIREMENTS
- OPERATIONS ARE:
  - CONSULT WITH GROUND
  - UPDATE GUIDANCE COMPUTER
  - CONFIGURE AND ACTIVATE OMS
  - SECURE PAYLOADS
  - STORE AND SECURE SPECIMENS, TOOLS, TRASH, ETC
  - OPERATE OMS AND/OR ACPS TO ADJUST ORBIT IF REQUIRED
  - ADJUST ATTITUDE FOR DEORBIT BURN AND VECTOR CONTROL
  - AFTER BLACKOUT, ESTABLISH COMMUNICATIONS WITH GROUND
  - VERIFY POSITION AND VELOCITY AND PROJECTED LANDING PARAMETERS, PRIMARILY VIA TACAN SYSTEM

Figure 2-47. Space Shuttle Entry

## SPACE SHUTTLE LANDING AND POSTLANDING

It is expected that by the end of L-band (TACAN) blackout, the landing site will have line-of-sight with the space shuttle and can coordinate the landing approach with the crew. Tactical Air Navigation (TACAN) System, Microwave Landing System (MLS), and unified S-band (USB) (ground radar) may be used to verify the landing parameters and assist in the energy management.

Initiate postlanding operations will provide for safing the orbiter and its payload, as well as off-loading of those data and specimens that require rapid removal. Subsequently, the orbiter will be prepared for nominal payload removal. The time to remove the payloads needs to be kept minimum to expedite space shuttle turnaround, as well as mission evaluation. It is estimated that this could be accomplished in approximately 4 hours for most KSC landings. Landings elsewhere will require payload unloading, but probably will not receive the same urgent attention as that given by KSC.

- AUTOMATIC AND MANUAL LANDING CONTROL WILL BE PROVIDED
- SYSTEMS SUCH AS TACAN SYSTEM AND MLS WILL BE AVAILABLE FOR LANDING ASSISTS
- VOICE COMMUNICATION CHANNELS WILL BE AVAILABLE FOR COORDINATION WITH GROUND
- GROUND TRACKING IS DESIRABLE FOR USE IF AVAILABLE FOR GROUND LANDING MANAGEMENT
- CRITICAL POSTLANDING OPERATIONS:
  - PURGING AND VENTING OF REACTANTS AND HIGH-PRESSURE TANKS
  - OFF-LOADING OF TIME-CRITICAL DATA AND SPECIMENS
- TIME EXPECTED TO NORMAL PAYLOAD REMOVAL WILL BE ABOUT 4 HOURS, DEPENDING ON THE PAYLOAD NEED AND LANDING SITE

Figure 2-48. Space Shuttle Landing and Postlanding

## COMMUNICATIONS OVERVIEW

To discuss operations concepts, one needs to define the scope of the operation, which is illustrated in this figure. The total operations involves not just the space shuttle, but also the payloads that it delivers to orbit, the payloads that it is required to service on orbit, the ground supporting systems such as Space Tracking and Data Network (STDN), a satellite system such as the projected Tracking and Data Relay Satellite System (TDRSS), ground communications systems, launch and landing facilities, and all associated interfaces. In addition, for earth observations missions, aircraft underflights and ground truth sites may be involved.

Concepts for experiment data handling, STDN, and TDRSS will be discussed here and in later figures. The frequency bands shown reflect the most recent planning. Specific channels are obviously design issues to be resolved in design and development of the space shuttle and payload systems.

This operations concept suggests that the space shuttle is not an island cut off from the rest of the world, but, instead, does have communications with an operations management center that extends itself to remote flight control consoles and remote experiment consoles, providing the operations management function defined earlier. Launch and landing operations are coordinated with other on-going operations through the operations management center, as is auxiliary flight control (i.e., flight control of payloads unique to expertise and support systems of other locations, as ERTS is to GSFC). The experiment operations are considered "on-line" (i.e., data acquired during flight and transmitted to ground can be reviewed by appropriate parties and a near-real-time response made). As proposed in the next figure, the ground experiment "on-line" concept provides a continuous operational capability, but not all experiments are expected to require continuous ground operations. Experiments appear to fall into different categories: (1) experiments that require long periods of data taking and real-time manned support, such as observatories; (2) experiments that require man-in-the-loop to set up checkout and/or activate and check periodically; and (3) experiments that require man-in-the-loop because man is the test object, such as the biomedical-type experiments. The extent to which man on board the space shuttle and/or on the ground is required is a mission variable and must be considered for each situation. Thus, the "on-line" concept is intended to be responsive to periodic, as required, operations.

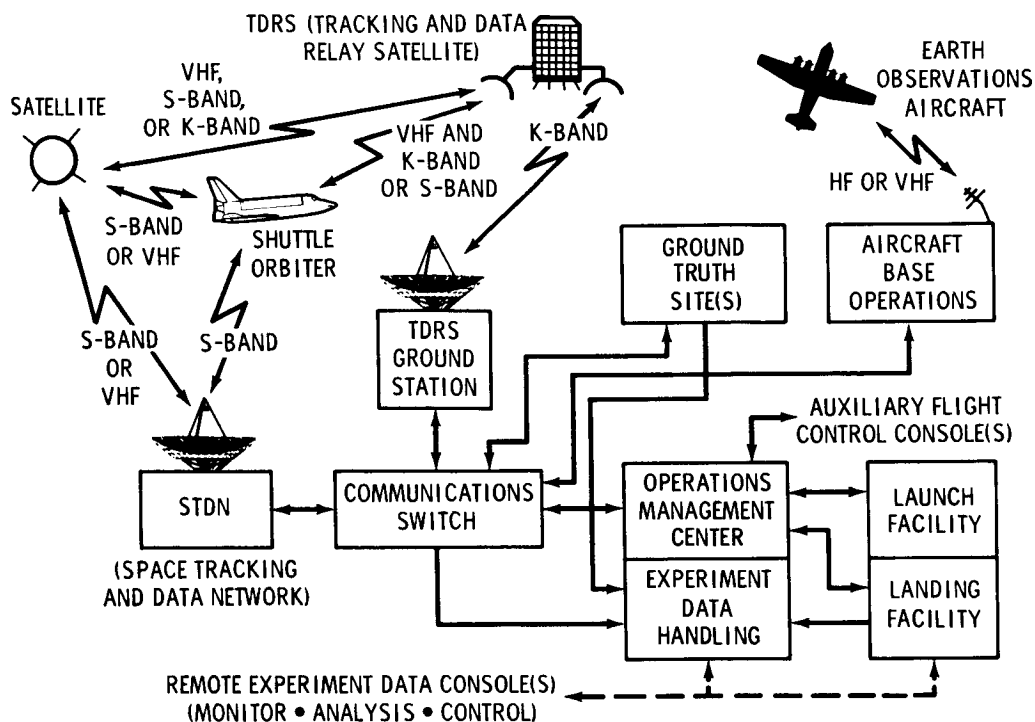


Figure 2-49. Communications Overview

## BASIC EXPERIMENT DATA HANDLING OPERATIONS

The fundamental objective of the proposed concept is to make the data available to the user as soon as possible (mission time if practical) in a format suitable to his analysis, with minimum manipulation (processing and handling) by other ground facilities.

To this end and to the extent practical, the space shuttle and/or payload data system will acquire and record (store) the data with correlative data in a format directly applicable to the analysis. A study conducted by IBM for MSFC suggests that this procedure be done on board according to scientific disciplines. To the extent that it is appropriate and practical, these recommendations will be followed. It is apparent, however, that a proliferation of onboard tape recorders presents a problem that must, therefore, be carefully evaluated.

In addition, to satisfy near-real-time support and to complement the onboard data handling, some additional ground operations are expected, as shown in the



figure. The degree to which each of these operations will be accomplished is a mission variable. All processing requirements must be evaluated on an as-required or as-specified basis to ensure an optimum approach. The preferred concept suggests a central control with diverse operations (processing) to make maximum use of existing capability and to be convenient to the user.

- TO THE EXTENT PRACTICAL, DATA WILL BE ACQUIRED AND RECORDED ONBOARD IN A FORM COMPATIBLE WITH DELIVERY DIRECTLY TO MISSION PAYLOAD CENTERS
- FOR NEAR REAL TIME, AND TO AUGMENT THE ABOVE, THE GROUND WILL PERFORM THE FOLLOWING OPERATIONS
  - PREPARATION OF DATA IN STANDARD OR USER-REQUESTED FORMATS
  - IMAGERY CORRECTIONS
  - ANNOTATION AND CALIBRATION
  - CATALOGING
  - TEMPORARY STORAGE AND RETRIEVAL FOR NEAR REAL TIME OPERATIONS
  - REPRODUCTION AND DISTRIBUTION FOR SPECIAL REQUIREMENTS
  - SUPPORT FOR PERMANENT ARCHIVES
  - SPECIAL PROCESSING TO ACCOMMODATE DIRECT APPLICATION OF MEASURED PARAMETERS

Figure 2-50. Basic Experiment Data Handling Operations

## COMMUNICATIONS COVERAGE

Office of Tracking and Data Acquisition (OTDA) and GSFC have made some projections regarding future spacecraft-to-ground interface (i.e., STDN and TDRSS) for the late 1970's and early 1980's. The next four figures will be concerned with this subject.

The total of the ground stations shown on this figure is the result of combining the MSFN and STADAN (with some eliminations from both) into one network, now called STDN. As far as the space-to-ground interface is concerned, GSFC personnel expect to have very similar capability implemented at all these sites in time for the space shuttle development period. Present GSFC planning strongly suggests the development of a TDRSS that would be implemented in time for the operational phase of the space shuttle. In combination with the development of an operational TDRSS, the STDN would be reduced to only those

shown with antenna coverage patterns. Current plans do not include the Hawaii station, but it is shown here as a possible support element because of studies done at both the MSC and MSFC that show Hawaii to have a significant supportive role. The patterns are representative of the coverage which would be provided to space shuttle orbits of 100 and 240 nautical miles in altitude.

Therefore, if OTDA and GSFC are permitted to implement the plan, and if space shuttle and/or payloads provide proper interfacing systems, communications will be via these five or six STDN stations and a two-satellite relay system with basic capabilities, shown in the next two figures.

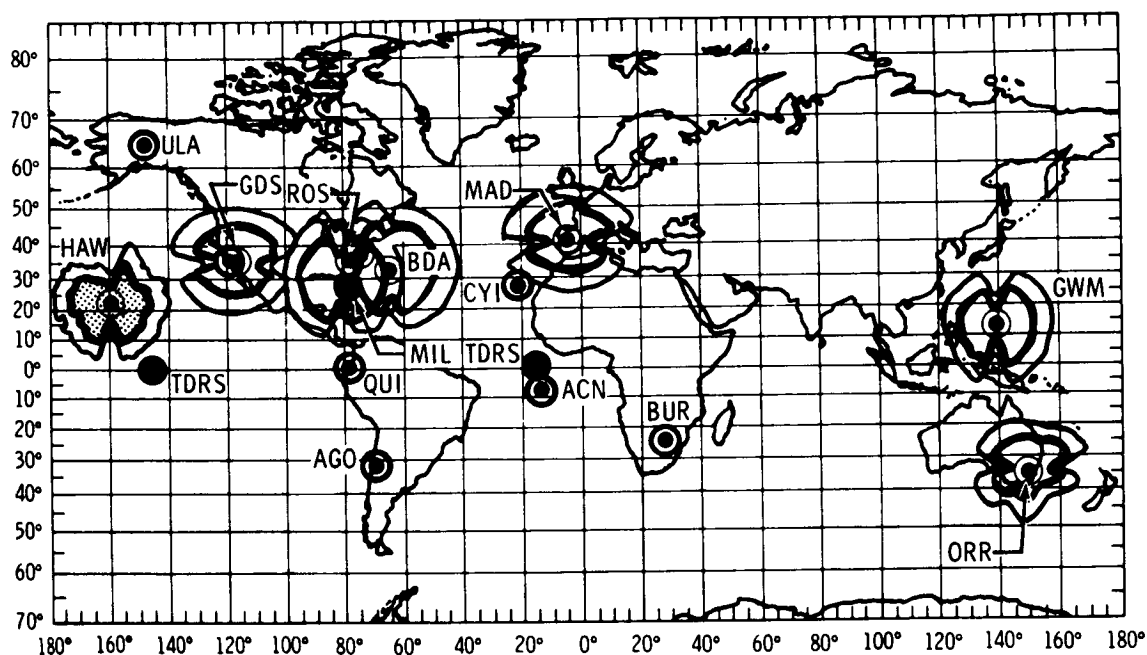


Figure 2-51. Communications Coverage

## 1975 STDN STATION CAPABILITIES

The GSFC planning suggests a 1975 STDN composed of the stations listed (representing a combination of the MSFN and STADAN) having basic information channels indicated by V, C, T, R. The VHF links do not show voice channels because those systems are the STADAN telemetry, command, and tracking systems. Voice channel capability can be added if desired.

All stations will have ground (point-to-point) communications to the Goddard communications switch, providing some level of real-time data transmission.

Presently, this transmission is on the order of 7.2 to 36 Kbps, depending upon the mission requirement and station design. Requirements of 72 to 240 Kbps are projected that, according to OTDA, are feasible for the space shuttle operations era. These circuits are leased from commercial carriers so that the primary consideration is one of cost.

Goddard maintains a document, STDN No. 101.1, "Space Flight Tracking and Data Network Users Guide," that contains more specific information for anyone who desires more detail. The latest edition is revision 1, dated April 1972.

STATION	S-BAND	VHF**
	2025 TO 2120 MHz XMIT 2200 TO 2300 MHz RCV	148 TO 154 MHz XMIT 136 TO 138 MHz RCV
ALASKA (ULA)	V,C,T,R	C,T,R
ASCENSION ISLAND (ACN)	V,C,T,R	C,T
BERMUDA (BDA)	V,C,T,R	C,T
CANARY ISLAND (CYI)	V,C,T,R	C,T
GOLDSTONE (GDS)	V,C,T,R	C,T
GUAM (GWM)	V,C,T,R	C,T
HAWAII (HAW)	V,C,T,R	C,T
JOHANNESBURG (BUR)	V,C,T,R	C,T
MADRID (MAD)	V,C,T,R	C,T
MERRITT ISLAND (MIL)	V,C,T,R	C,T
ORRORAL VALLEY (ORR)	V,C,T,R	C,T,R
QUITO (QUI)	V,C,T,R	C,T
ROSMAN (ROS)	V,C,T,R	C,T,R
SANTIAGO (AGO)	V,C,T,R	C,T,R

V - VOICE C - COMMAND T - TELEMETRY R - RANGING  
 \* REAL-TIME DATA HANDLING IS AVAILABLE FOR ALL STATIONS  
 \*\* VOICE CAN BE ADDED. FOR SPECIFIC CAPABILITIES, SEE GSFC  
 STDN NO. 101.1, APRIL 1972, REV 1

Figure 2-52. 1975 Space Tracking and Data Network Station Capabilities \*

## FLIGHT CREW INTEGRATION FOR SHUTTLE/PAYLOADS

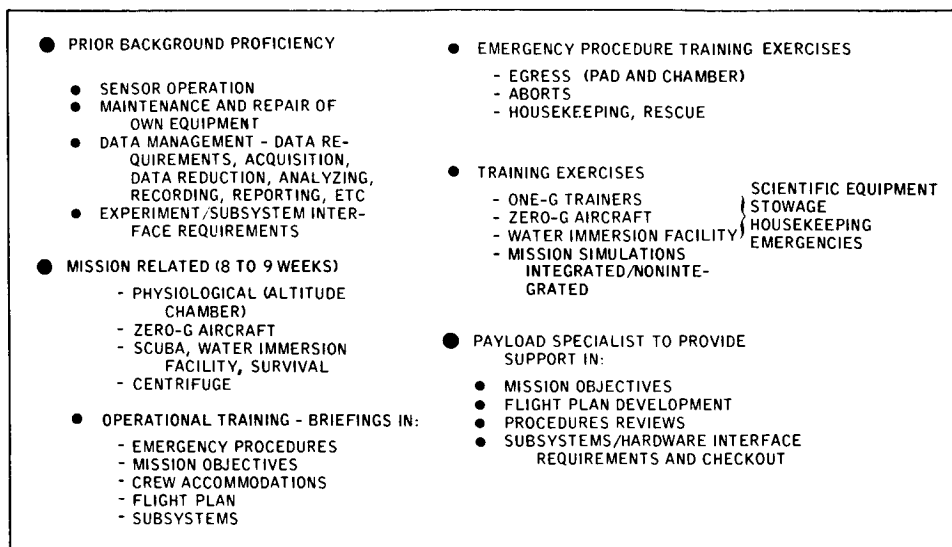


Figure 2-53. Typical Space Shuttle Training for the Payload Specialists

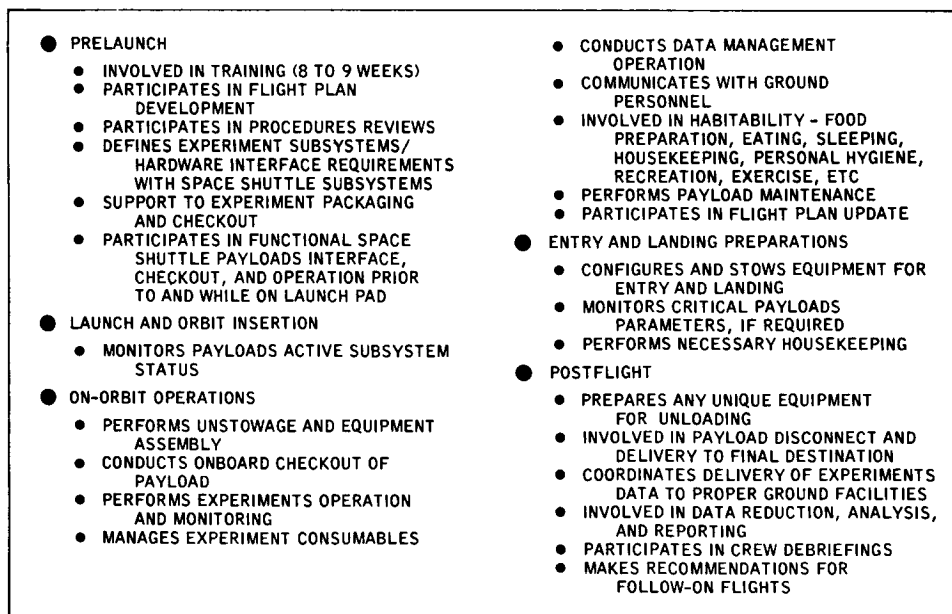


Figure 2-54. Typical Operational Role of Payload Specialist

- EXTRAVEHICULAR ACTIVITY AVAILABLE AS A NORMAL OR CONTINGENCY PROCEDURE FOR PAYLOAD OPERATIONS, WHERE IT CAN BE SHOWN TO BE COST-EFFECTIVE AND/OR DESIRABLE
- TWO SUITED CREWMEN REQUIRED FOR EXTRAVEHICULAR ACTIVITY OPERATIONS (BUDDY SYSTEM)
- ACCOMPLISHED BY MISSION SPECIALISTS, COMMANDER, OR PILOT
- MISSION SPECIALISTS AVAILABLE TO ASSIST AND/OR PERFORM PAYLOAD MAINTENANCE, DEPENDING UPON NATURE OF TASK

Figure 2-55. Extravehicular Activity Operation/Maintenance

### SPACE SHUTTLE PAYLOADS PREPARATION PLANNING SUMMARY

In summary, the Space Shuttle Program has major milestones that provide for initial payload opportunity in calendar year 1979 with an expanding operational capability in 1980 and beyond. Considerable activity has occurred and will continue on the identification, sorting, selection, definition of priorities, and preparation for implementation of many future payloads.

The three payload classes of standard payload carriers have been introduced: the sortie labs/airlocks/platforms, the free flying or automated satellites, and the automated satellites with added propulsion stages (kick stages). This standard hardware is in support of the requirements of three major payload areas: applications, technology, and science. The mission payload hardware is provided by mission payload centers and the respective experiment teams. The NASA Centers, other U.S. Government agencies, U.S. universities, U.S. industry, and the international community are the payload suppliers. The total space shuttle flights per year increase from six to 60 for current planning purposes, with the capability of using the Eastern Test Range (Kennedy Space Center) or the Western Test Range (for south polar launches). The exact number of space shuttle systems has not been determined as of this date, although planning has been based on five orbiters. The space shuttle performance capability has a wide range of operations for circular and elliptical orbits in low inclinations to polar and sun synchronous orbits. The use of added propulsion stages with the payloads provides the opportunity to obtain geostationary orbits and to undertake deep space probe missions.

It should be emphasized that the foregoing space shuttle information is baseline and not specification data. The system can be expected to undergo changes as the design evolves and specifications are drawn. The system will be designed to respond in a disciplined manner to the emergence of new requirements, changes will be documented for the users in the Baseline Accommodations for Payloads document.

SECTION 3

PRESENTATION

OF THE

SORTIE LAB CHARACTERISTICS AND PLANS

AT THE

SPACE SHUTTLE SORTIE WORKSHOP

JULY 31-AUGUST 4, 1972

## INTRODUCTION

This section of the proceedings of the Space Shuttle Sortie Workshop, July 1972, describes concepts for payload carrier modules (both pressurized and unpressurized) designed for a variety of orbital research and applications uses while attached to the shuttle orbiter vehicle. On sortie missions the experimenters' equipment will normally interface directly with one of these carrier modules rather than with the shuttle itself, more specifically, either with the Sortie Lab in which men and women can work in a shirtsleeve environment or on the pallet when the experimenters' equipment requires continuous direct space exposure.

The following section consists of three parts: an overview and two appendices. The overview starts with objectives and system philosophy, then describes the results of several preliminary concept studies, and the principal supporting activities and ends with a discussion of alternative implementation plans. The overview is based on material presented by D. R. Lord, Headquarters, W. R. Marshall, W. T. Carey, H. G. Craft, all of Marshall Space Flight Center, D. R. Mulholland of Ames Research Center, and W. R. Hook of Langley Research Center (see References).

Attachment I describes the utilization characteristics of one particular system concept in considerable depth, including its mission and performance characteristics, and the physical and operational interfaces that a potential user would encounter. The material in this appendix should be considered a strawman baseline of a very preliminary nature and without the benefit of either a firm shuttle design or authoritative requirements from the user community.

Attachment II presents the top level (headquarters imposed) guidelines and constraints to be used in the course of the program definition study just getting underway on Sortie Lab. Consequently, the material in the second appendix represents more recent thinking than that in the first appendix, but this material is also very preliminary and can and will be changed when good reasons appear.

## SORTIE LAB OVERVIEW

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## REFERENCES

1. "Sortie Lab Development and Supporting Activities," Douglas R. Lord
2. "Experiment/Sortie Laboratory Experiment Interfaces," William R. Marshall
3. "Shuttle Payload Planning and Design Data," Harry G. Craft
4. "CV-990 Analog and Sortie Mode Simulation," Donald R. Mulholland
5. "General Purpose and Dedicated Laboratory Concepts for Sortie Mode,"  
    William T. Carey
6. "Advanced Technology Laboratory — Shuttle Sortie," W. Ray Hook



## SORTIE LAB OVERVIEW

The term "Sortie Lab" applies to a class of payload carriers, both pressurized modules and unpressurized instrument platforms or pallets, which will remain attached to the shuttle orbiter throughout a 7 to 30 day-mission, and is the space analog of the Convair 990 used in the Airborne Science Program by Ames Research Center. Sortie Lab is an early version of the RAM (Research and Applications Module) family and emphasizes low cost. This class of vehicle has also been called Sortie Can, Sortie Module and Sortie RAM depending on which group developed the concept, but they are all basically the same. Aside from experiment missions, Sortie Lab may also be used for servicing automated satellites and for development missions as an instrumentation carrier for the Shuttle or as a test bed for measuring the induced environment. The latter two missions are rather speculative at this time.

### OBJECTIVES

The Sortie Lab program objectives are listed below:

- The program will strive to provide a versatile capability for accommodating laboratory and observatory facilities suitable for shuttle sortie missions at the lowest practical investment, both in development and operating costs.
- The program will capitalize on the experience of the Airborne Science Program in which scientists bring their laboratory instruments on-board the Ames Convair 990 and other aircraft, and are directly responsible for the successful conduct of their experiments.
- An objective closely related to the second, the program will try to reduce significantly both the time and cost required for space experimentation.

The final two objectives may be thought of as alternatives to one another.

- NASA will accomplish a major step towards internationalizing the post-Apollo program, if the Europeans decide to develop the Sortie Lab with their own resources.
- On the other hand, if the Europeans do not make this decision, the Agency will use in-house capabilities, as much as possible, to build Sortie Lab in order to reduce R&D funding requirements.

## DESIRED CHARACTERISTICS

Based on these objectives a number of desired characteristics for the Sortie Lab system and program have been identified and shown in Figure 3-1. More detailed requirements will result from user involvement and analysis like the Space Shuttle Sortie Workshop, July 31, 1972-August 4, 1972.

First, the Sortie Lab system will emphasize multiple reuse, simplicity and use of proven components and, in some cases, subsystems which are common with the shuttle as means of achieving low cost. Insofar as practical the system will be compatible with using ground laboratory equipment similar to the Ames Airborne Science Program.

Second, the Sortie Lab system will be designed with versatile accommodations as a primary goal. It should provide the ability to house and support payloads made up of one or two major facilities like telescopes or made up of a number of different laboratory devices and pieces of experiment equipment from several

- **LOW COST**
  - SIMPLICITY
  - MINIMUM NEW DEVELOPMENT
  - SUITABLE FOR
    - IN-HOUSE BUILD, OR
    - EUROPEAN DEVELOPMENT
  - USE OF GROUND LAB EQUIPMENT ONBOARD
- **LABORATORY VERSATILITY**
  - MULTIDISCIPLINE OR SINGLE DISCIPLINE
  - ALL UTILITY SERVICES - SUPPLEMENTING SHUTTLE AS REQUIRED
  - BASIC LABORATORY EQUIPMENT
  - LARGE PRESSURIZED VOLUME
  - SHIRTSLEEVE ENVIRONMENT
  - UNPRESSURIZED INSTRUMENT PLATFORM (ORBITER OR LAB SUPPORTED)
  - WIDE VIEWING ANGLES
  - EXPERIMENT INSTALLATION POSSIBLE AT USER'S FACILITY
- **MINIMUM INTERFERENCE WITH SHUTTLE TURN-AROUND**
  - SIMPLE SHUTTLE TO MODULE INTERFACE
  - PRIMARY CHECKOUT INDEPENDENT OF SHUTTLE
- **RAPID EXPERIMENT CYCLE-CONCEPT TO RESULTS**
  - DIRECT USER INVOLVEMENT
  - MINIMUM QUALIFICATION REQUIREMENTS
  - MINIMUM DOCUMENTATION

Figure 3-1. Desired Characteristics for Sortie Lab

disciplines. Another major goal of this versatility is to make it possible and convenient for users to install their experiments themselves on pallets, in racks or in module sections and then ship these assembled experiments to NASA for integration and installation in the total Sortie Lab and then in the shuttle. The Sortie Lab will provide work space pressurized to one atmosphere with oxygen and nitrogen for the scientists who go along on missions as well as large airlocks and the pallet for experiments needing space exposure. The pallet experiments will normally be controlled from the Sortie Lab module, but the pallet can fly on missions without the pressurized module by direct attachment to the orbiter and with control from the orbiter cabin. Utility services including power, thermal control, data recording and processing, communications, and stabilization will all be provided within the limits imposed by cost considerations.

Third, the Sortie Lab system and operations will be designed for minimum interference with shuttle turnaround activities on the ground so that the shuttle can be returned to flight status as rapidly as possible. This characteristic will require a simple interface between Sortie Lab and the orbiter in both hardware and software aspects. It will also require independent checkout.

Fourth, the Sortie Lab system and operations will promote rapid access for users and rapid return of experimental data. This will be accomplished through the direct involvement of the investigators, through minimizing the qualification test requirements on their experiment equipment and through reducing the formal documentation compared to current space research practice.

Figure 3-2 shows a generalized concept for the Sortie Lab resulting from the desired characteristics in Figure 3-1. In contrast to the Space Shuttle the Sortie Lab is just at the beginning of its definition phase and essentially no final design decisions have been made. In this concept the Sortie Lab remains in the shuttle orbiter payload bay and is attached by a tunnel to the orbiter crew compartment. The crew of mission specialists, payload specialists and passenger observers would all ride and live in the orbiter and work in the pressurized compartment of the Sortie Lab. While crew sizes of 2 to 6 (in addition to 2 crewmen operating the shuttle) are being considered, a crew of 4 currently appears to be cost effective. The Sortie Lab will supplement orbiter utilities (power, stabilization, data processing, thermal control, etc.) as required by the users insofar as practical and will provide controls and displays, recording equipment, equipment racks, airlocks, deployment booms, viewing ports, etc. Experiments requiring wide angle viewing and direct space exposure can be mounted on the pallet and operated remotely from the Sortie Lab pressurized compartment. If the viewing is not adequate with this arrangement or if there is not sufficient exposed surface to reject heat loads the Sortie Lab

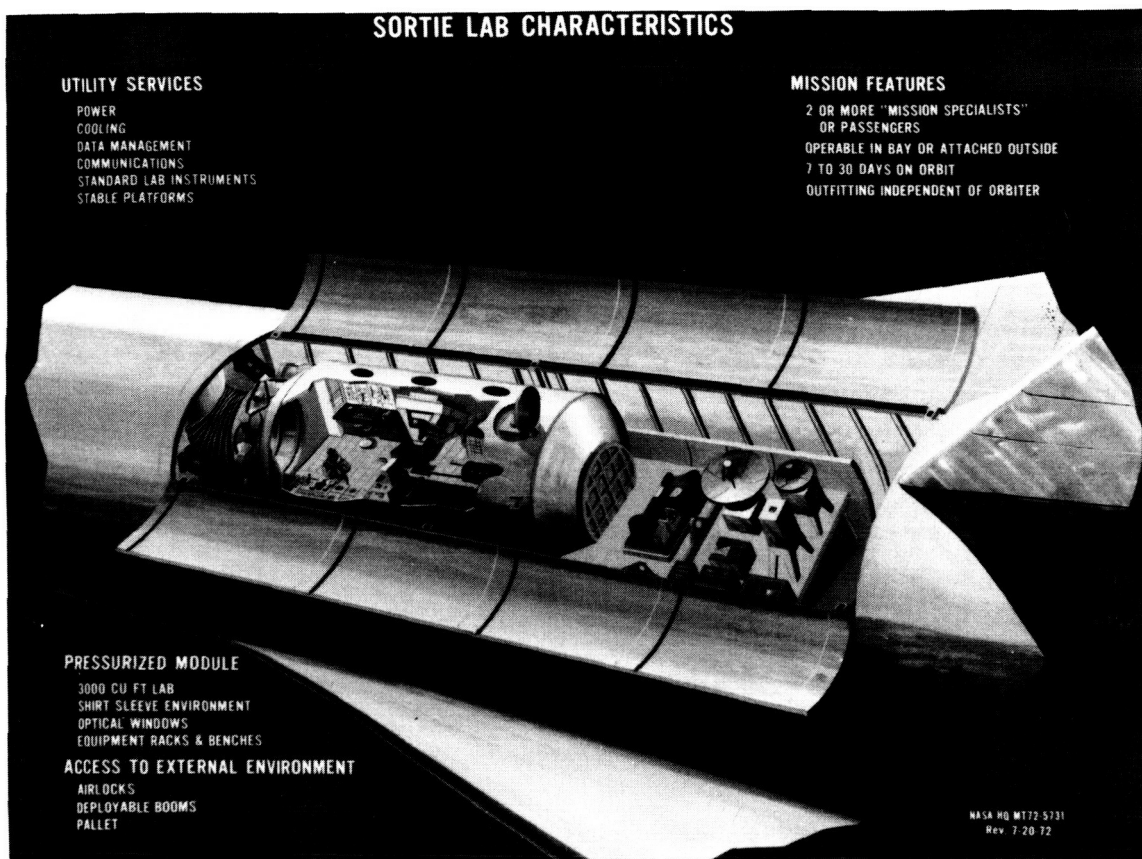


Figure 3-2

may be rotated out of the payload bay. Extendible booms could also be used to meet wide angle viewing requirements.

### COMPLETED CONCEPTUAL DESIGN STUDIES

A number of studies which have resulted in concepts for Sortie Lab have been completed as shown in Figure 3-3. Marshall Space Flight Center conducted an in-house study specifically addressing module concepts for shuttle sortie missions in late 1971. Results of that study are described briefly later and more extensively in Appendix I. MSFC has now initiated a program definition activity on Sortie Lab which will lead to a preliminary design late next year.

General Dynamics/Convair conducted a twelve-month study of Research and Applications Modules (RAMs) covering a whole family of shuttle compatible laboratory vehicles which could eventually evolve to applications with a

<b>MSFC</b>	<b>IN-HOUSE STUDY</b> <b>SEPT. 71 TO JAN. 72</b>
<b>GENERAL DYNAMICS-CONVAIR</b>	<b>RAM PHASE B DEFINITION</b> <b>MAY 71 TO MAY 72</b>
<b>MCDONNELL DOUGLAS</b>	<b>SOAR STUDY</b> <b>JAN. 71 TO JAN 72</b>
	<b>IN-HOUSE STUDY</b> <b>OCT. 71 TO JAN 72</b>
<b>NORTH AMERICAN ROCKWELL</b>	<b>MODULAR SPACE STATION STUDY</b> <b>FEB. 71 TO NOV. 71</b>

Figure 3-3. Conceptual Studies of Sortie Modules

semi-permanent space station. One of the family of modules investigated in this study was a so-called Sortie RAM. McDonnell Douglas studied a broad spectrum of shuttle payloads in their SOAR (Shuttle Orbital Applications and Requirements) study including, in the first phase, concepts for a Sortie Lab. MDAC supplemented the contract study work with an in-house effort concentrating on a very low cost approach. North American Rockwell also looked at concepts for Sortie Labs during the latter phase of their Modular Space Station study.

In addition to these American studies, three European studies of Sortie Lab are currently underway and are described in the last section of this paper. The results of the two American studies which developed the most depth, the MSFC in-house study and the GDC study, are described on the following pages.

#### MSFC In-House Concept (also see Appendix I)

Figure 3-4 is an artist's rendering of the MSFC concept which is designed for in-house development and construction. It particularly stresses low cost and maximum use of Apollo, Skylab and shuttle subsystems and components. The pressurized module is 26 feet long and 15 feet in diameter, and, exclusive of experiment instrumentation, weighs approximately 12,000 pounds. Repressurants and cryogens are stored in tanks located around the forward bulkhead outside the pressurized volume.

MSFC CONCEPT  
BASELINE SORTIE CAN



Figure 3-4

The interior of this Sortie Lab concept is laid out in a single floor arrangement parallel to the cylinder axis. MSFC designed a relatively autonomous Sortie Lab with minimum dependence on the shuttle orbiter subsystems in order to simplify the orbiter-to-Sortie Lab interface. The subsystems in this Sortie Lab concept occupy the forward half of the pressurized module along with a crew station for monitoring subsystems and experiment operations, a work bench for general experiment support and removable equipment racks. A system of standardized interconnects with the experimenters' equipment was planned but not detailed for thermal control, electrical power and data management.

Based upon an analysis of experiment requirements conducted during the study, two large airlocks were incorporated into the design. A folding boom arrangement is provided for deploying experiments out of the airlocks. The concept in Figure 3-4 shows a major portion of the Lab's interior is available for installation of the user's own equipment and instruments.

In the MSFC concept the pallet can be used either alone as shown in Figure 3-5 or in conjunction with the pressurized module. The open truss pallet in this concept is itself modularized to match the length requirements of the particular complement of instruments to be mounted for a given mission. In addition to serving as the basic mounting platform for instruments requiring direct space exposure, the pallet provides connections for electrical power, thermal control,

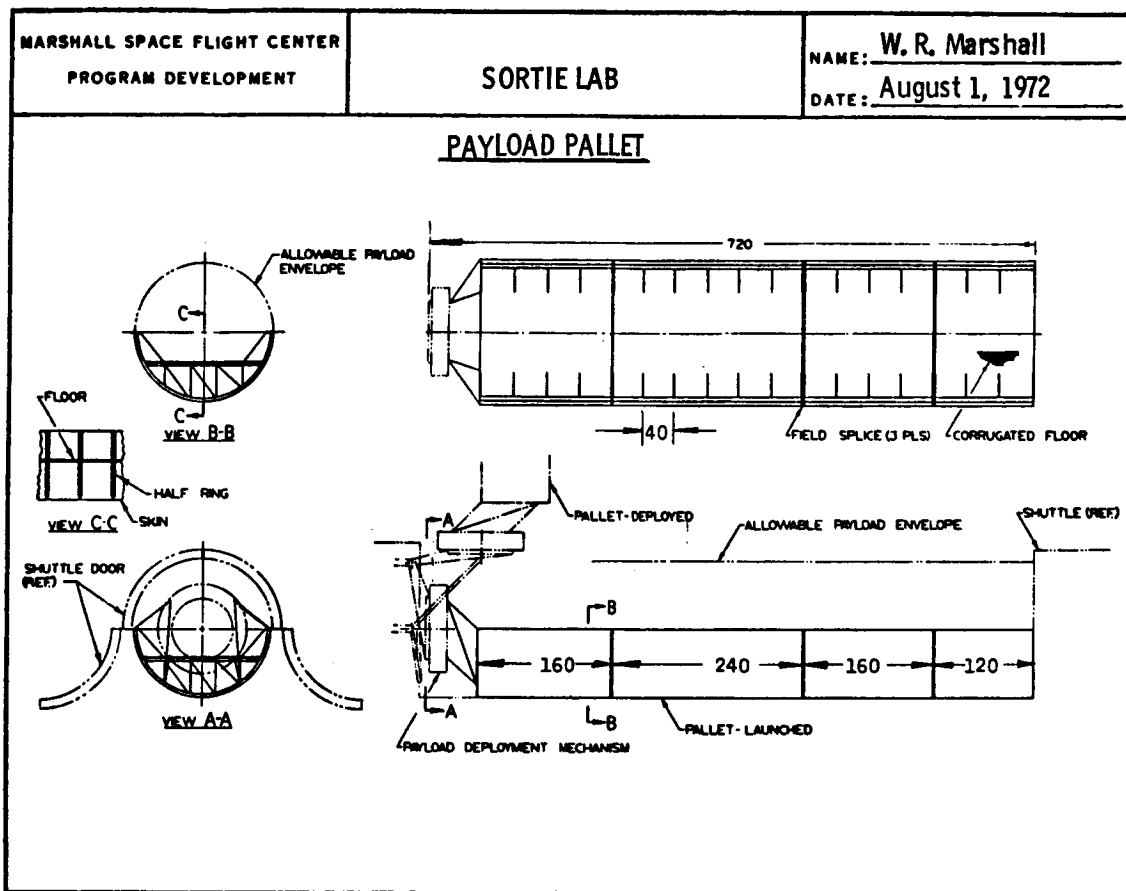


Figure 3-5

control and data circuits, and stable platforms. To enable users to observe instruments mounted on the pallet, windows are provided in the aft bulkhead of the pressurized module. Television can also be provided for indirect viewing.

Although MSFC found that deployment of the Sortie Lab out of the shuttle orbiter payload bay has a number of attractive features (additional heat dissipation, wide viewing angles, etc.), the additional cost associated with a deployment mechanism, the requirement for more rigid structure and the associated loss of payload weight and volume resulted in their concentration on a nondeployed module and pallet.

A summary of the experiment support requirements developed in the MSFC study is shown in Figure 3-6. This chart is very difficult to read because it summarizes so much material, but it does help to show the analysis process. Each bar represents the cumulative support requirements of a combination of





instruments believed to be logical and representative of a single Sortie Lab mission. The symbols in each bar designate the predominant experimental discipline:

AST	Astronomy
EO	Earth Observations
MS	Materials Science
P/C	Physics and Chemistry
SP	Space Physics
PP	Plasma Physics
LS	Life Sciences
C/N	Communications and Navigation

Selection of the level of experiment support to be provided by the Sortie Lab and whether it should supplement or be independent of the shuttle orbiter capabilities is both an analytical and a judgment process. Figures 3-7 and 3-8 show

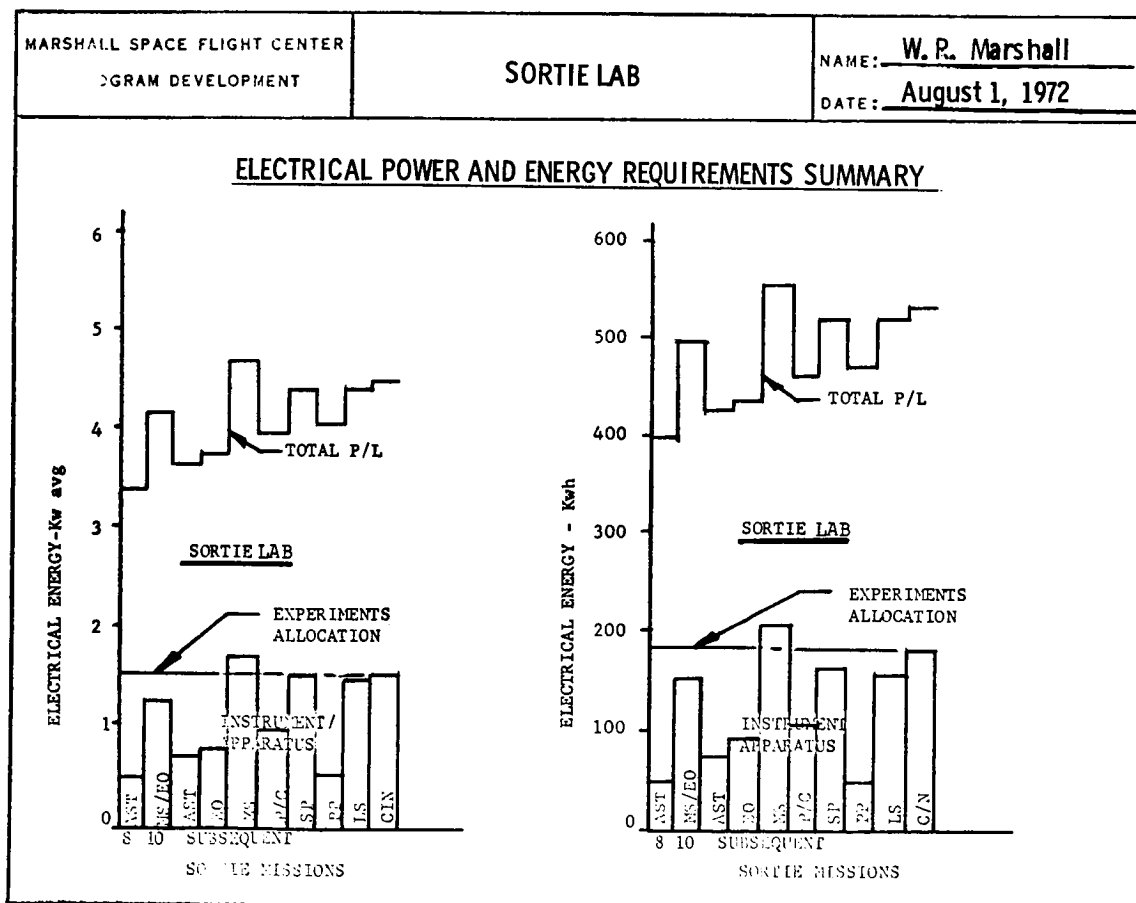


Figure 3-7

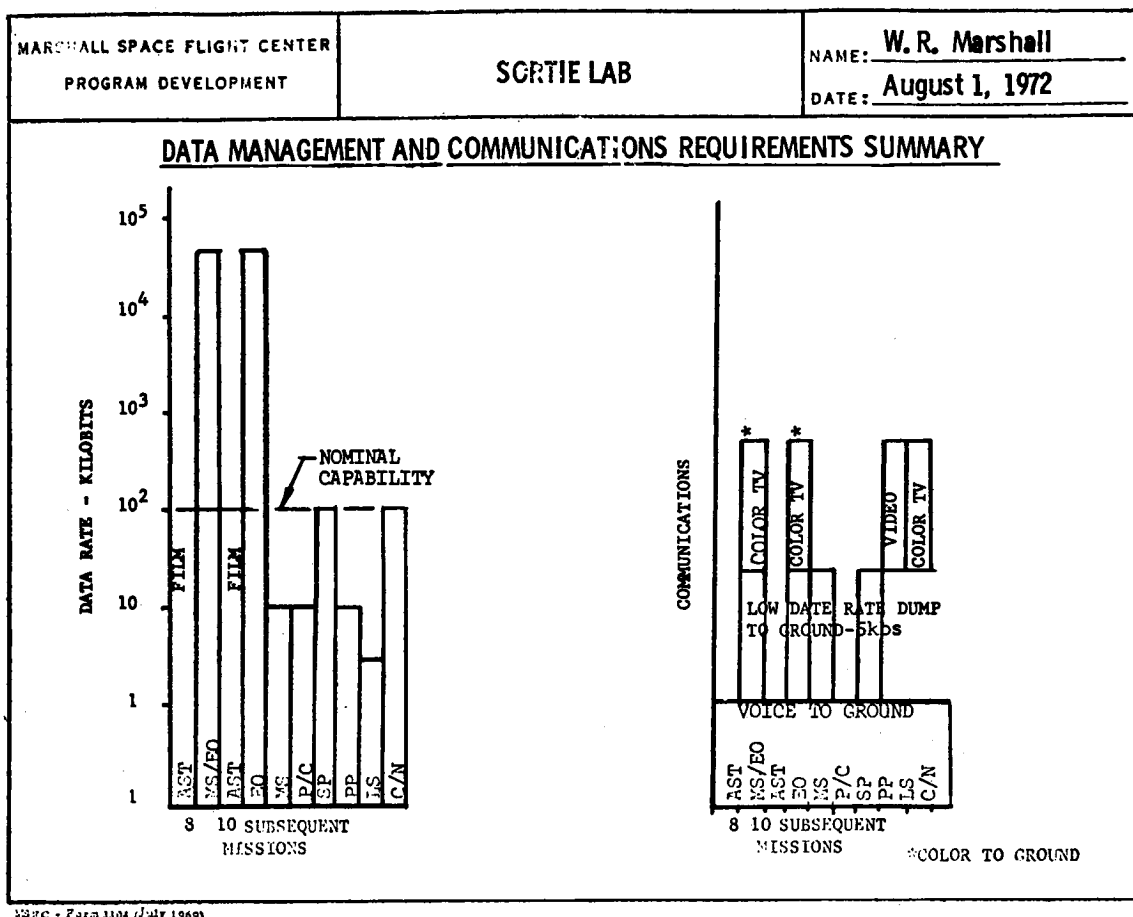


Figure 3-8

expanded versions of the requirements for power and data management. Looking at Figure 3-7, the power required for the experiments and the power required to operate Sortie Lab subsystems add to determine the total requirement. In the MSFC conceptual study another constraint, radiator area, severely limited the total power consumable in the Sortie Lab so that the average power available to users was only 1.5 kw. Ways will have to be found to remove this constraint. During the definition study, the impact of the requirements from additional logical combinations of experiments on the Sortie Lab arrangements and on its various subsystems will be analyzed. Repeated iterations to arrive at a sufficiently versatile and affordable laboratory and pallet design and operational concept will be performed.

## General Dynamics/Convair Concept

The concept developed by GDC as part of the RAM study was similar to the one developed by MSFC. The general arrangement is shown in Figure 3-9. The

### GENERAL DYNAMICS - CONVAIR CONCEPT SORTIE RAM GENERAL ARRANGEMENT

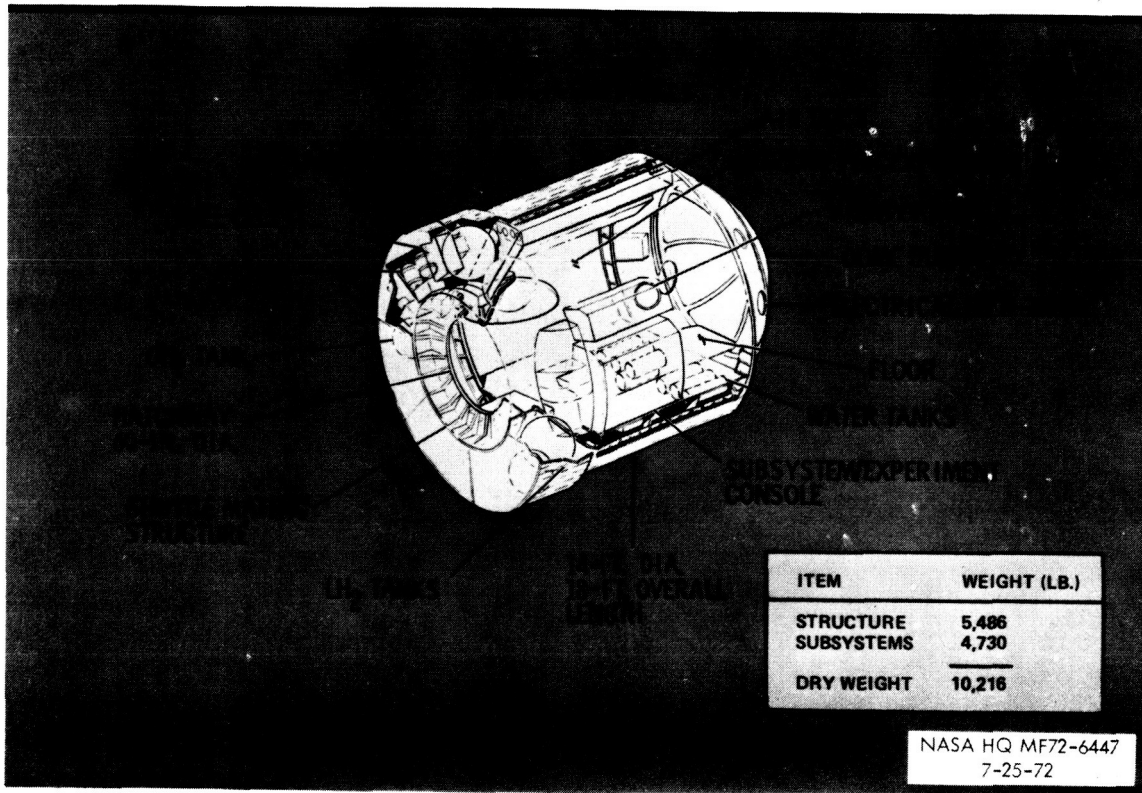


Figure 3-9

GDC module is eight feet shorter than the MSFC concept and is designed for deployment out of the payload bay, although always remaining attached to the orbiter. The GDC concept provides less volume in the pressurized module for experiments than the MSFC design, although, as later figures will show, it is still very spacious. If and when additional experiment volume is required, the GDC concept provides for another module, essentially void of subsystems except for a utility distribution system, to be attached to the aft bulkhead of the basic Sortie Lab module and to be parasitic to it. This feature appears to be

quite attractive from the viewpoint of users since an add-on module without subsystems would be less expensive than the basic Sortie Lab and might easily be "owned" and outfitted by individual user groups.

The GDC concept has another interesting design feature. The aft bulkhead of the basic module can be replaced either with a special bulkhead with a docking port for servicing automated satellites or with other special bulkheads designed to support particular experiment activities and external sensors. This arrangement is an alternative to a pallet, but neither one precludes the other.

The pallet concept developed by GDC, Figure 3-10, is 25 feet long and weighs approximately 2000 pounds. It is designed for rigidity in a deployed condition with a control moment gyro system attached to the pallet stabilizing the complete spacecraft, orbiter plus Sortie Lab, for extended periods at pointing

## PALLET ARRANGEMENT GENERAL DYNAMICS- CONVAIR CONCEPT

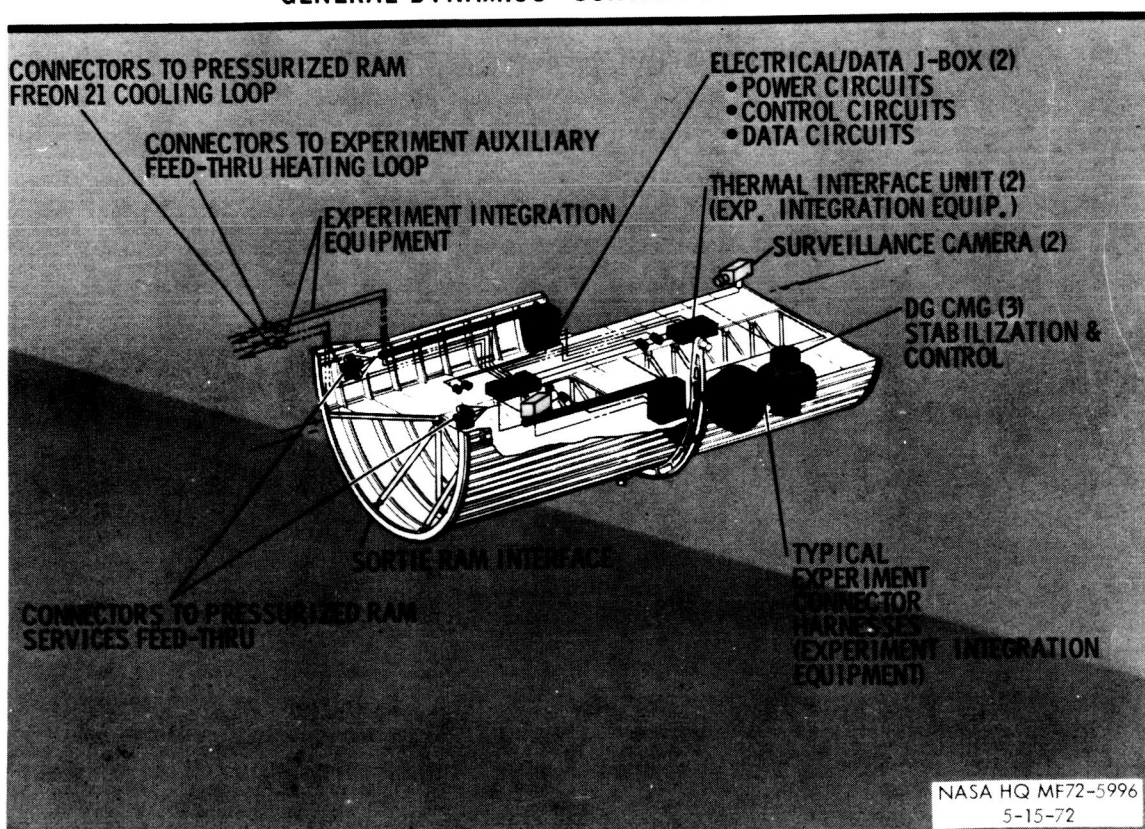


Figure 3-10

accuracies on the order of 30 arc sec and without the contamination associated with reaction controls. The pallet is also designed to carry gimballed instrument platforms which point with an accuracy on the order of 1.0 arc sec.

Figure 3-11 summarizes the user provisions in the GDC Sortie Lab concept. A "shirtsleeve" environment is provided by precise control of temperature, humidity and atmospheric composition at a sea level pressure. The inclusion

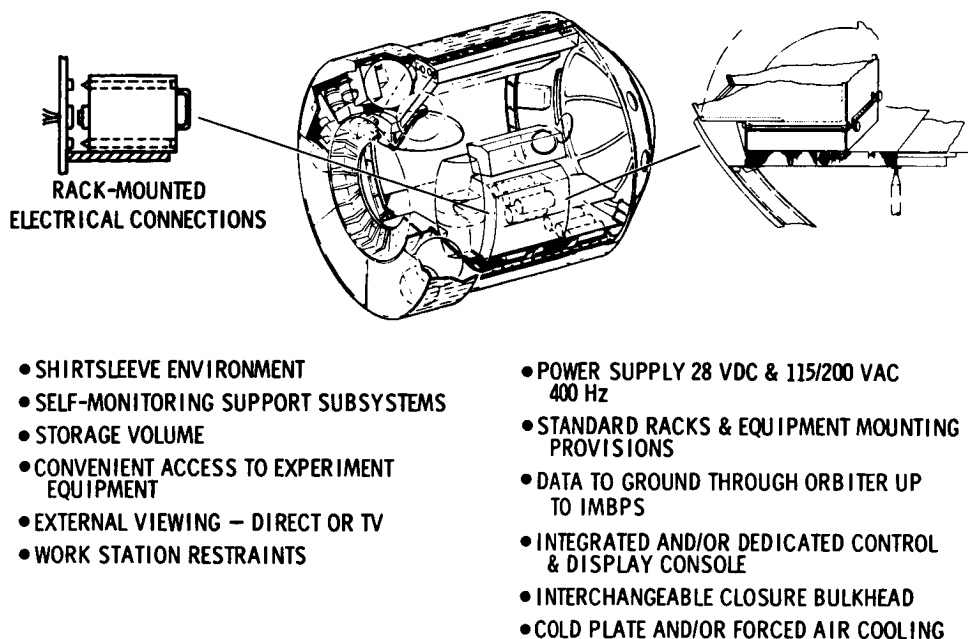
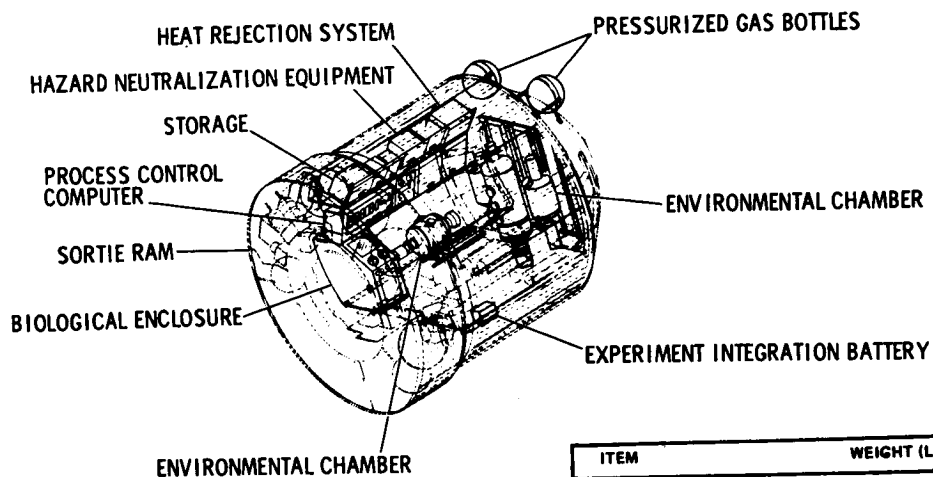


Figure 3-11. User Accommodation Provisions Sortie Ram

of self monitoring features on the support subsystems will permit the Payload Specialists in the crew to spend the majority of their time conducting experiments. In the GDC concept both 28V DC and 115/200V AC power are provided. Both cold plates and forced air are provided for cooling experiment equipment and standardized racks are provided for mounting experiment equipment. The GDC control console provides for both integrated and dedicated displays. Communications to the ground at rates up to 1M bps are provided for data sampling and consultation with colleagues through the shuttle orbiter system.

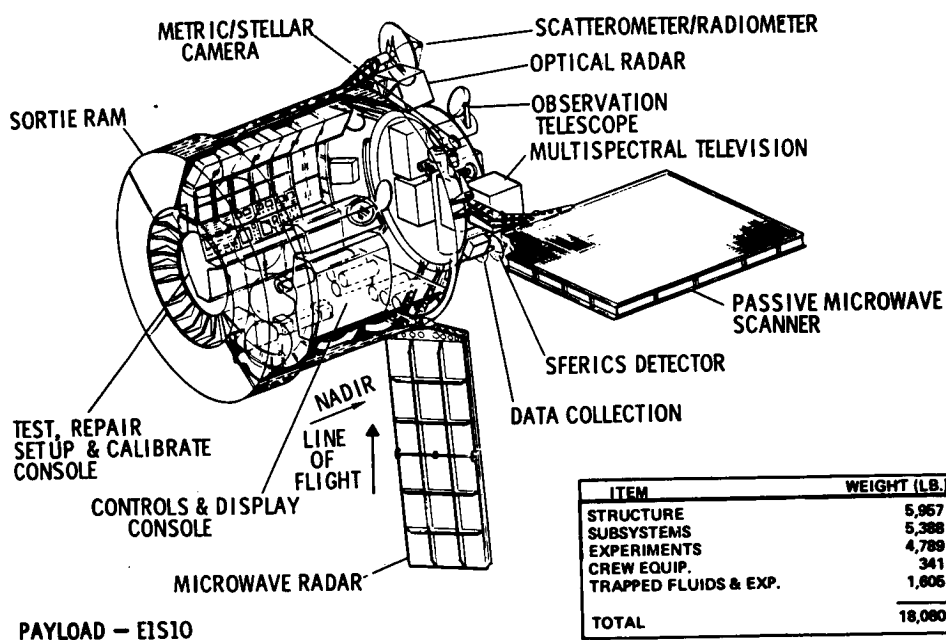
Figures 3-12, 3-13, and 3-14 illustrate three applications of the GDC Sortie Lab outfitted for particular disciplines. Figure 3-12 illustrates a Material Science arrangement, Figure 3-13 illustrates an Earth Observations arrangement with sensors mounted external to the aft bulkhead, and Figure 3-14 shows



PAYLOAD - MISIE

ITEM	WEIGHT (LB.)
STRUCTURE	5,486
SUBSYSTEM	5,586
EXPERIMENTS	3,100
CREW EQUIPMENT	341
RESIDUALS, RESERVES & EXP.	1,747
<b>TOTAL</b>	<b>16,240</b>

Figure 3-12. Materials Science Sortie Mission Payload



PAYLOAD - EIS10

ITEM	WEIGHT (LB.)
STRUCTURE	5,967
SUBSYSTEMS	5,388
EXPERIMENTS	4,789
CREW EQUIP.	341
TRAPPED FLUIDS & EXP.	1,605
<b>TOTAL</b>	<b>18,080</b>

Figure 3-13. Earth Observations Sortie Mission Payload

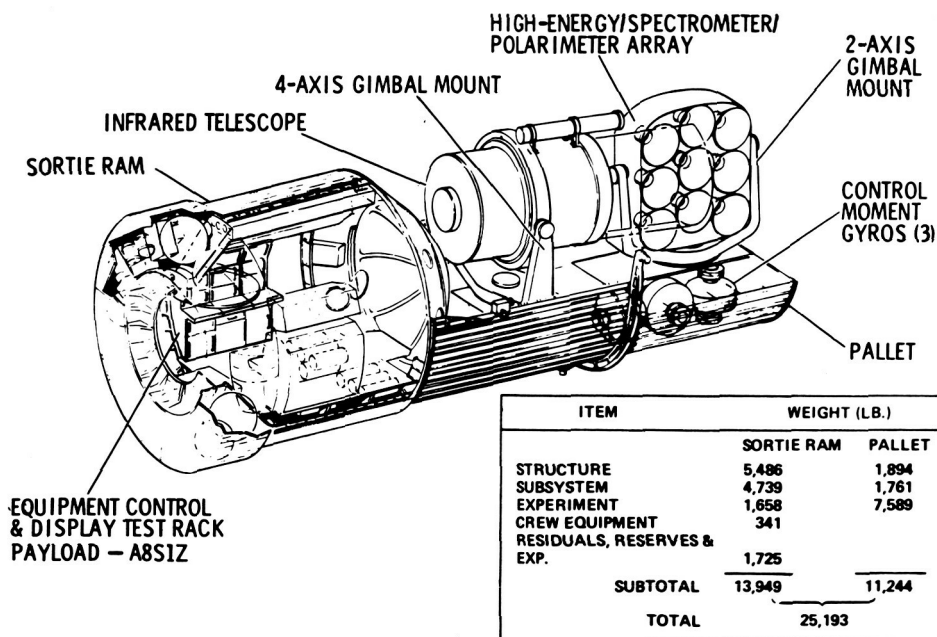


Figure 3-14. Astronomy Sortie Mission Payload

the use of the combined Sortie Lab module and pallet arranged for an Astronomy mission.

Figure 3-15 shows the interior of a soft mockup of the Material Science arrangement and illustrates how spacious a module 14 feet in diameter and 18 feet long is. Furnaces and environmental chambers are shown mounted on the open grid floor, and instrument racks, control panels and storage compartments are shown mounted on the walls. The crewman is shown pulling out a control panel to gain access to the backside and to the wall.

#### Sortie Lab Characteristics Summary

Figure 3-16 summarizes the basic characteristics of the Sortie Lab concepts developed to date. Physically the Lab module would have a pressurized volume of 2000 to 3000 cubic feet contained in a cylinder 18 to 26 feet long. It would weigh 10,000 to 12,000 pounds empty and some 18,000 to 25,000 pounds when outfitted with experiment equipment. The pallet would be 24 to 32 feet long based on current understanding of its use. Unloaded it would weigh 2000 to 4000 pounds and as much as 12,000 pounds with experiment equipment. Average power in the 7 to 14 kw range for combined subsystem and experiment loads could be provided although heat rejection will be a major problem if the high level is required for an extended period. Most of the conceptual study has concentrated on a crew size of two in addition to two shuttle pilots although limited

## SORTIE RAM SOFT MOCKUP

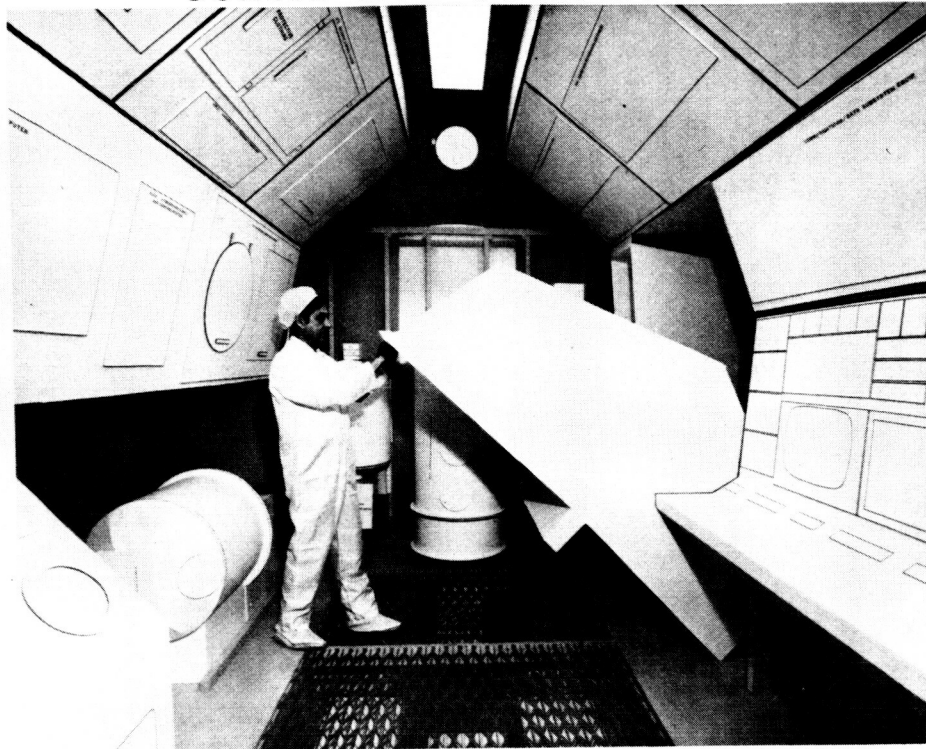
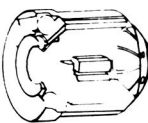



Figure 3-15

RAM ELEMENT	LENGTH (FT)	WEIGHT (LB) BASIC LOADED	PRESSURED VOLUME (CU. FT)	POWER* KW KWH	MISSION DURATION	CREW SIZE	DEVELOP** COST (\$M)	UNIT** COST (\$M)
<b>SORTIE LAB</b> 	18-26	10-12K TO 18K	2-3K	0-14 0-1000	7-30 DAYS	2-6	200	25
<b>PALLET</b> 	24-32	2-4K TO 12K	0	0 0	7-30 DAYS	0	15	3

\* ADDITIONAL TO POWER SUPPLIED BY ORBITER

\*\* WITHOUT EXPERIMENTS

Figure 3-16. Sortie Lab Summary



consideration has been given to crew sizes up to six, primarily in terms of a two shift operation.

Assuming design and development by a prime contractor the cost of the current Sortie Lab concepts is estimated to be on the order of \$200 million for development and \$25 million for each unit. Pallet costs would be in the \$15 million range for development and in the \$3 million range for each unit.

### CURRENT SORTIE LAB ACTIVITIES

Figure 3-17 shows that current Sortie Lab program schedule starting with definition study activity through delivery of flight units. The shuttle schedule is shown at the top of this figure for comparison. The Sortie Lab design phase (Phase C) is now not expected to get underway until after the middle of CY 1974 (or FY 1975) and the first flight unit (Number 3) will not be outfitted with experiments and ready to fly until mid CY 1979. A development module is shown

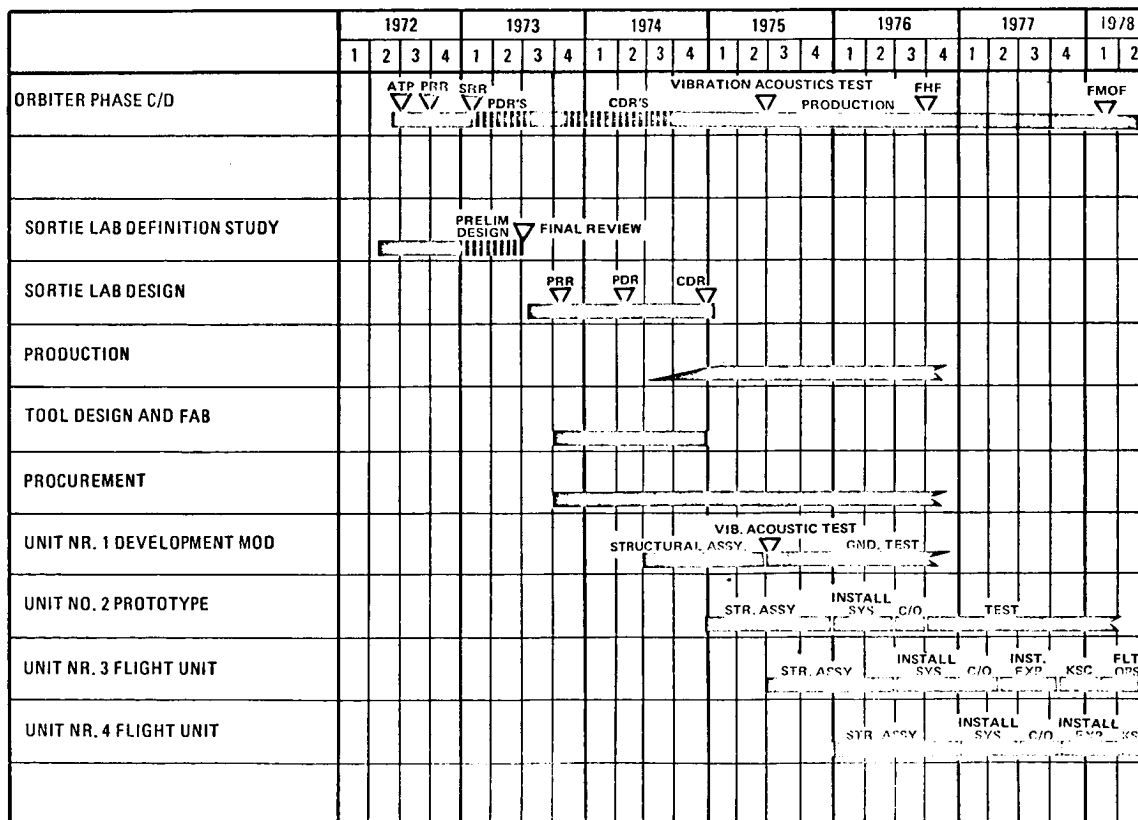


Figure 3-17. Shuttle/Orbiter - Sortie Lab Schedule Relationships

in this plan for structural tests and a prototype for complete systems qualification and for simulation and training activity.

Figures 3-18A and 3-18B summarize all the principal activities related to Sortie Lab underway at the present time.

#### In-House Definition Study (MSFC)

While the agency is actively pursuing discussions with the Europeans on the possibility that they may decide to develop a Sortie Lab, a complete program definition study is getting underway with the Marshall Space Flight Center as the lead center. This study is directed towards making extensive use of in-house capabilities during the design and development phases. The current level I guidelines and constraints for this program definition study are presented in Appendix II. Figure 3-19 is a flow diagram for the Phase B definition study and shows all its major features. However, it is greatly simplified because it doesn't show the iterative loops, or the major inputs from the shuttle

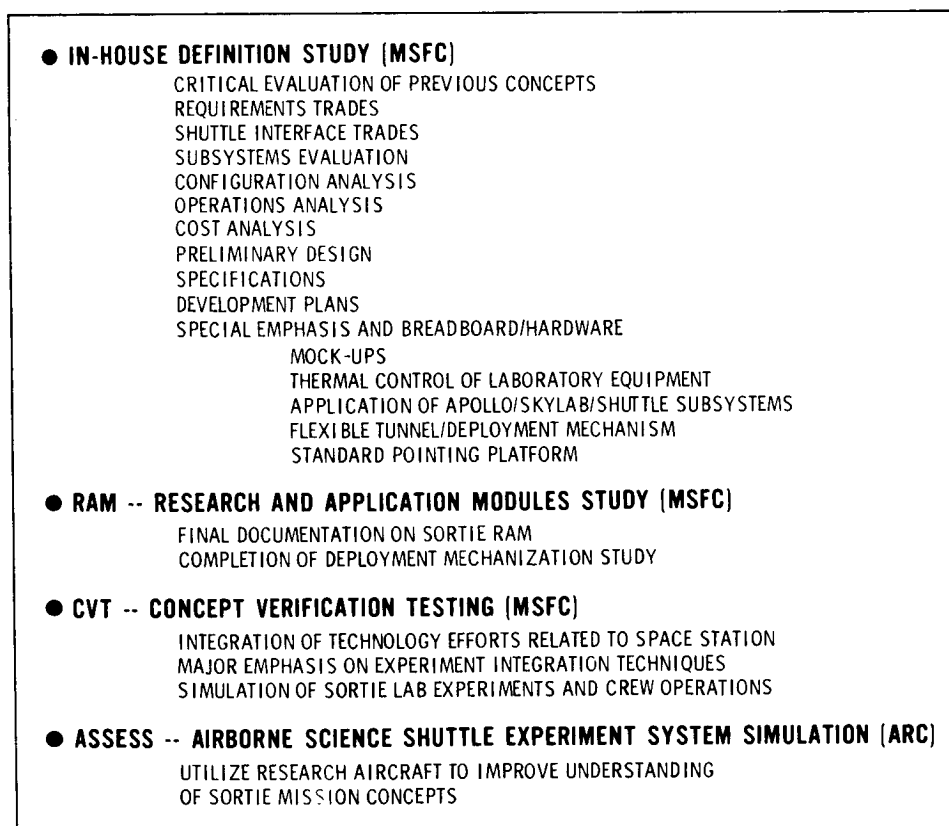


Figure 3-18A. Current Sortie Lab Related Activities - I

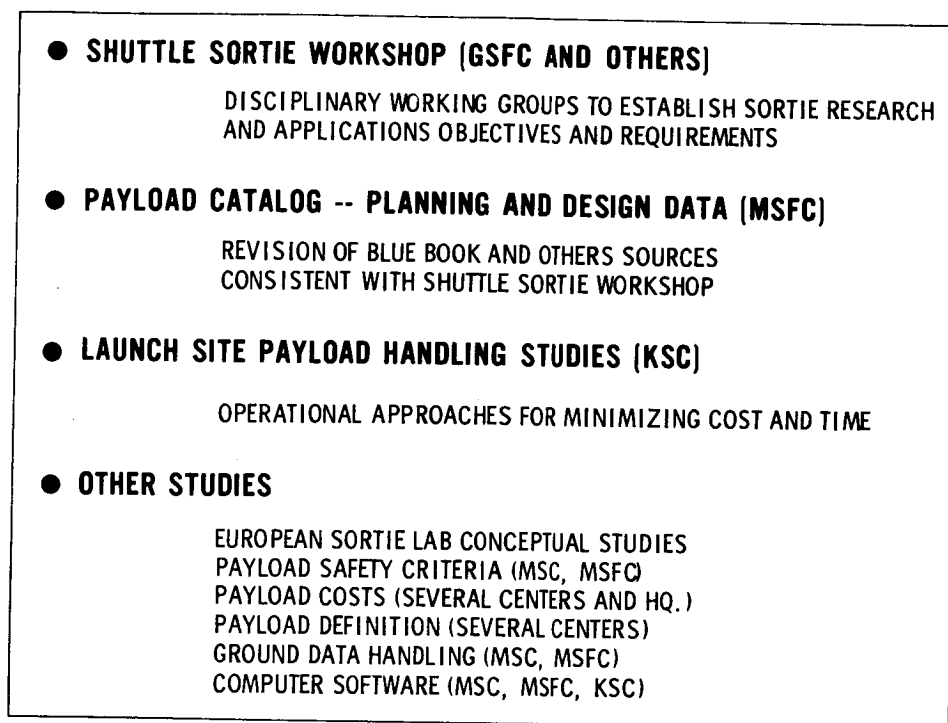


Figure 3-18B. Current Sortie Lab Related Activities - II

program and from user requirements activities like the Shuttle Sortie Workshop. In addition the schedule shown along the bottom is no longer valid since preliminary design will probably continue into the fall of 1973. This should allow time to incorporate those requirements identified by users in the next year which can be afforded.

Figure 3-18A lists not only tasks which are part of the definition study itself, but also a number of special emphasis tasks.

- **Mock-ups** — Two mock-ups are under construction and will be revised as the studies progress. The mock-ups are available at MSFC for inspection and suggestions from the user community will be welcome.
- **Thermal Control** — Thermal control tasks are planned with emphasis on the best ways of using equipment designed for other purposes and of cooling equipment not designed for the space environment (i.e., forced air cooling in addition to cold plate design).
- **Available Subsystems** — A special emphasis task is planned to continue investigation in more depth of the suitability of Apollo and Skylab

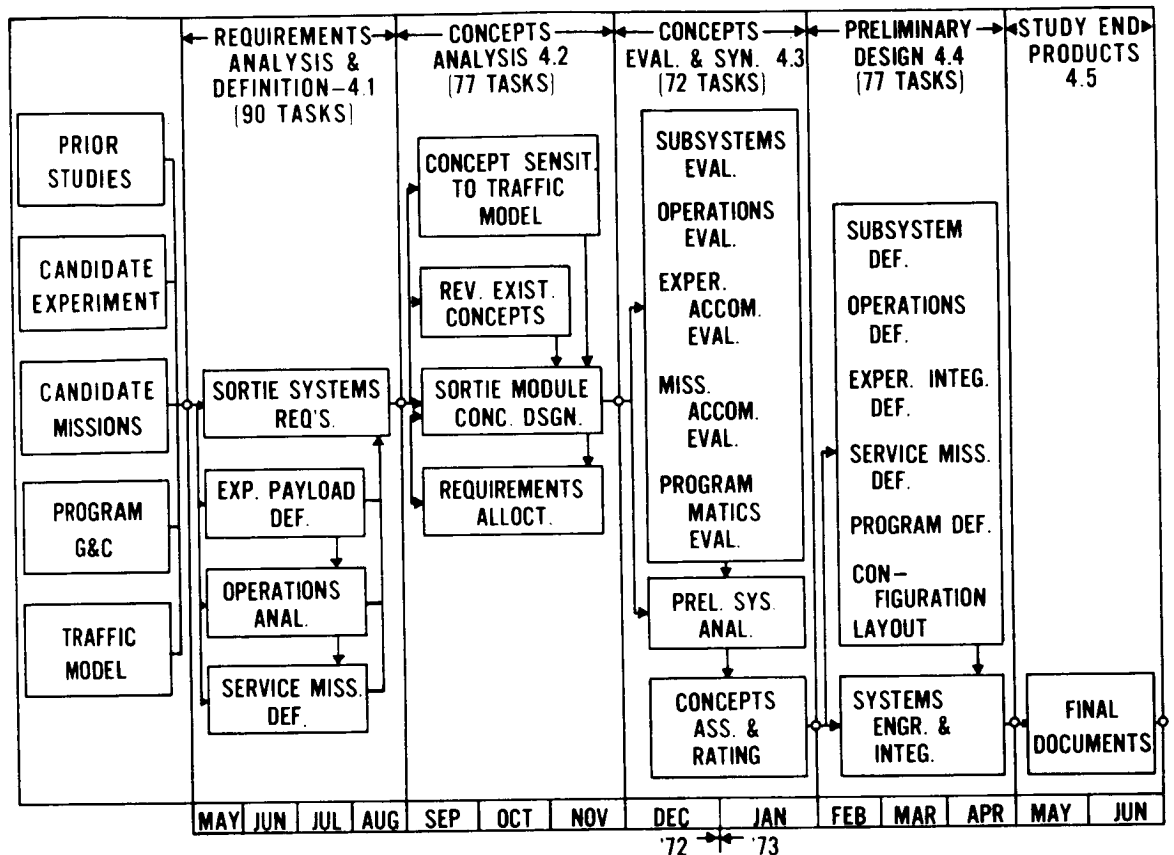


Figure 3-19. Sortie Lab Phase B Logic

components and subsystems, and shuttle components and subsystems when they are defined for Sortie Lab and pallet applications.

- **Deployment Mechanisms** — A special task involving both analysis and test hardware is underway on flexible tunnel systems which may be required to connect the shuttle orbiter to the Sortie Lab if the Lab is rotated out of the payload bay.
- **Standard Pointing Platform** — A special task is planned to evaluate the feasibility of "standard" stabilized platforms or gimbal systems that could be mounted on the pallet and would be suitable for many experiment applications requiring fine pointing and stabilization.

Other activities referred to in Figure 3-18A include the RAM study conducted by General Dynamics Convair under MSFC direction the results of which have been described earlier in this paper and now in the final documentation phase,

and CVT or Concept Verification Testing which is primarily directed towards advancing and integrating the technology efforts applicable to future space stations. However, some of the early emphasis on CVT will be to simulate the system interactions between crewmen and experimental equipment which may be typical of shuttle sortie missions. Another program underway which will directly simulate Sortie Lab type operation is ASSESS.

### ASSESS

This acronym stands for the Airborne Science Shuttle Experiment System Simulation which is being carried out by the Airborne Science Office at Ames Research Center. ARC has operated aircraft as platforms for scientific research and application activities for several years and it is their work in the past with the Convair 990 that has stimulated much of the Sortie Lab concept to date. The program operates under streamlined management and operational concepts. Experimenters are provided basic utilities such as electric power and standardized equipment racks while the experimenters themselves provide their own instruments and are responsible for obtaining data, performing analyses and publication of results. ASSESS is a special program to translate the best features of the Airborne Research Program into space flight operations. Figure 3-20 shows the principal characteristics of the aircraft Ames is currently using in their science program. Two of these aircraft, the Lear Jet and the CV-990, will be used in ASSESS. Starting in the fall of 1972 the Lear Jet with two pilots and two investigators will fly real science missions under simulated space isolation conditions. The men will eat and sleep in a trailer and will fly two sorties a night for a period of several days constituting one mission. The crew will have no direct contact with other personnel and will be entirely responsible for keeping the experimental equipment in working order. At a later date the much larger CV-990 will be reconfigured in the cabin to more nearly simulate Sortie Lab and shuttle orbiter internal provisions and the crewmen will actually live onboard. Insofar as possible and within reasonable constraints ASSESS will exercise the total Shuttle Sortie mission concept as shown in the operational objectives, Figure 3-21. Scientists from outside of NASA will participate in the program and will help to develop recommended procedures for scientists who will participate in future shuttle sortie missions. The program should also provide additional insight into management concepts for experiments and into the effects of work cycles, training and pre-flight planning upon experimenters. The study elements for the ASSESS program are listed in Figure 3-22.

Figure 3-18B lists several other important Sortie Lab related activities. These include the Shuttle Sortie Workshop itself and the important follow-on activities with representatives of the user community outside of NASA. The Sortie Lab

# NASA-AMES AIRBORNE SCIENCE AIRCRAFT

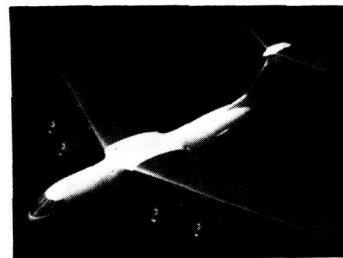
CV 990



LEAR JET



C141



## PERFORMANCE

PAYLOAD, 6,800 kg  
RANGE, 3,300 n.mi.

## OBSERVING TIME

	(km)	(kft)	
ABOVE	12.3	40	3.0 hr
	13.7	45	1.0

## PERFORMANCE

PAYLOAD, 454 kg  
RANGE, 1,700 n.mi.

## OBSERVING TIME

	(km)	(kft)	
ABOVE	12.3	40	3.6 hr
	13.7	45	3.0
	15.3	50	.7

## PERFORMANCE

PAYLOAD, 11,362 kg  
RANGE, 5,250 n.mi.

## OBSERVING TIME

	(km)	(kft)	
ABOVE	12.3	40	8.5 hr
	13.7	45	~ 3.5
	15.3	50	TBD

Figure 3-20

- EXERCISE TOTAL SHUTTLE PROGRAM CONCEPT
- APPLY LAUNCH AND FLIGHT SCHEDULE CONSTRAINTS
- OBTAIN PARTICIPATION OF NASA AND OUTSIDE SCIENTISTS
- RECOMMEND PROCEDURES FOR SCIENTIST PARTICIPATION IN SHUTTLE SORTIE MISSIONS
- ENHANCE DATA BASE FOR SORTIE MODULE DEFINITION AND EXPERIMENT MANAGEMENT CONCEPT
- DETERMINE EFFECT OF SHUTTLE-TYPE MISSION ON:
  - HARDWARE PREPARATION, CHECKOUT AND MAINTENANCE
  - EXPERIMENT/EXPERIMENTER INTERFACE
  - GROUND/AIR COMMUNICATIONS LINK
  - EXPERIMENTER WORK CYCLE
  - TRAINING AND PRE-FLIGHT PLANNING

Figure 3-21. Assess Program Operational Objectives

- MANAGEMENT STRUCTURE
- ROLE OF EXPERIMENTER
- INTERACTIONS BETWEEN EXPERIMENTER AND PROGRAM MANAGER
- METHOD OF EXPERIMENT SELECTION
- DESIGN AND CONSTRUCTION OF EXPERIMENTS
- EXPERIMENT CHECK-OUT
- INTERFACE REQUIREMENTS
- EXPERIMENT HARDWARE (OFF-THE-SHELF VS. CUSTOM)
- EXPERIMENT RELIABILITY
  - BREAK DOWN,
  - REPAIRS, ETC.
- SAFETY
- DOCUMENTATION

Figure 3-22. Assess Program – Study Elements

design team looks to the follow-on Workshop activity to establish definitive and authoritative experiment objectives and requirements. Based on these results a sortie payload catalog and data bank for the vehicle designers will be developed and preliminary plans for this catalog are well advanced at MSFC.

Another important area in the definition of Sortie Lab and other Shuttle payloads is launch site handling. Kennedy Space Center is studying methods for streamlining ground operations associated with experiment integration and with Sortie Lab checkout and installation in the Shuttle and refurbishment for subsequent missions.

In addition to these activities Figure 3-18B lists a number of other studies. The European activity will be described shortly. The other area of activity which is particularly important to Sortie Lab planning at the present is so-called payload definition.

#### Payload Definition

A number of studies are underway to develop conceptual designs of typical complete complements of experiments for Sortie Lab. These studies are basic

to understanding the suitability of a given Sortie Lab design. The studies begin with the selection of a typical set of candidate experiments for a particular discipline. Equipment and instruments are defined by first establishing functional requirements and then developing conceptual designs. Using current Sortie Lab module concepts, layouts are made for the conceptually designed equipment. This is followed by timeline analyses of crew activities, establishment of interfaces and an overall assessment of the research capability of the Lab to accomplish the assumed experiment objectives.

The MSFC Payloads Office presented their approach to the definition of "dedicated laboratories." Two interesting features of their approach is the emphasis on CORE equipment and the identification of potential commercial candidate equipment. CORE or Common Operations Research Equipment is defined as being basic research equipment for Sortie Lab that would be required for a number of experiments as opposed to experiment unique equipment. Figure 3-23 is a typical example of the CORE approach being taken in the definition study of a Communications and Navigation Research version of Sortie Lab. Typical experiments for such a Lab are listed across the top of the figure and equipment items are listed along the left. As an example, a Frequency Counter is necessary

ITEM									Equipment Location		COMMERCIAL CANDIDATE
	Tert. Sources of Noise	RF Propagation	Comm. Relay (TDRS)	Laser Comm.	Multibeam Antenna	Interferometer	Nav. & Surv. Landmark Tracking	External	Internal		
GENERAL PURPOSE COMPUTER	X	X	X	X	X	X	X		X		Honeywell DDP-516 24" x 24" x 38", 250 lbs, 1 KW
RF POWER METER		X	X		X				X		Weinschel PB-1B 19" x 12" x 8", 30 lbs, 50 W
SPECTRUM ANALYZER	X	X	X	X	X				X		Hewlett Packard HP 8551B 17" x 20" x 18", 122 lbs, 330 W
OSCILLOGRAPHIC RECORDER					X	X			X		Honeywell Visicorder 191Z 19" x 17" x 18", 170 lbs, 600 W
FREQUENCY COUNTER	X	X	X		X	X			X		Hewlett Packard HP 5240A 17" x 5" x 16", 34 lbs, 90 W
OPTICAL ANTENNA				X			X	X			Perkin Elmer 36" x 36" x 36", 10 lbs, 150 W
CAMERA (SCOPE)	X	X			X				X		Hewlett Packard HP 197A 8" x 11" x 14", 10 lbs

Figure 3-23. Common Core Equipment - Early Laboratory



equipment for five experiment areas. Down the right hand side of the figure are listed potential commercial candidates for each piece of experiment equipment. The objective of such an approach is to reduce inventory costs by promoting equipment commonality and reduce expenditures for development of equipment when a satisfactory commercial candidate might be available. No doubt the "available commercial candidate" would require some modifications prior to being used in Sortie Lab. However, this appears to be an attractive approach. The extent of modifications and their cost versus a new development will be the determining factor. Studies have been implemented to provide some answers here.

#### Advanced Technology Laboratory (ATL)

Another important activity in the payload definition area is a study called Advanced Technology Laboratory or ATL conducted by Langley Research Center to determine the feasibility of using the shuttle sortie mode as a direct extension of that center's research facilities and operations. One of the principal reasons for taking this line of investigation was the conviction that NASA will be better prepared to answer the questions of users from outside the Agency if we have thought through the questions of practical utility and procedures when applied to our own internal operations. The ATL study focused on research programs already underway at Langley and worked directly with the principal investigators. Concepts for experiment packages were developed for a number of disciplines and layouts were made for Sortie Lab configured for a multidisciplinary mode of operations. An important result of the study was the high degree of commonality between the flight experiments conceptualized for the ATL Sortie Lab and the center's ground based laboratory experiments.

#### PROPOSED ROLE FOR EUROPE

As a result of discussions between the United States and Europe, relative to their participation in post-Apollo space activities, serious consideration is being given by Europe to developing the first generation of Sortie Labs. Some of the specific aspects of this proposed role are listed in Figure 3-24. In this proposal Europe would work to United States specified user requirements, shuttle interfaces, safety and quality standards, systems engineering and configuration control methods, and schedule. Europe would deliver to NASA a functional mock-up, a flight test unit, two sets of ground support equipment, an initial set of spares as well as drawings and documentation. Europe would provide all the funding necessary to deliver this equipment and to work to United States requirements. The United States would plan to purchase one additional flight unit. While the United States would own and operate the Sortie

## **DESIGN AND DEVELOP THE FIRST GENERATION OF SORTIE LABS**

### **● WORK TO U.S. SPECIFIED:\***

- USER REQUIREMENTS
- SHUTTLE INTERFACES
- SAFETY AND QUALITY
- SYSTEMS ENGINEERING METHODS
- CONFIGURATION CONTROL METHODS
- SCHEDULE

### **● DELIVER TO NASA:**

- ONE FUNCTIONAL MOCKUP
- ONE FLIGHT TEST UNIT
- ONE FLIGHT UNIT (U.S. PURCHASE)
- TWO SETS OF GSE
- SPARES, DRAWINGS AND DOCUMENTATION

### **● PROVIDE ALL NECESSARY FUNDING**

\*NOTE THAT EUROPE WOULD PARTICIPATE IN:  
SHUTTLE PROGRESS REVIEWS  
SHUTTLE INTERFACE CONTROL  
USER REQUIREMENTS PLANNING

Figure 3-24. Proposed Role For Europe

Labs, Europe would have access to them for their own experiments regardless of their decision to develop the Sortie Lab. If Europe does decide to develop Sortie Lab they will participate in shuttle progress reviews, in the shuttle to payload interface control activities and, of course, in all aspects of user requirements planning.

At the present, Europe is conducting three conceptual design studies of Sortie Lab under the direction of the European Space Research Organization (ESRO) headquarters in Paris. The headquarters organization gets technical support from their space technology and research center (ESTEC) in Noordwijk, The Netherlands. Figure 3-25 summarizes the principal characteristics of these studies including the industrial concerns making up the three study teams. NASA will participate in progress reviews and concept selection.

- 3 INDUSTRIAL TEAMS\* \$250K TO 280K
- DIRECTED BY ESRO -- PARIS
- 7 MONTHS DURATION BEGINNING IN JUNE 1972

- NASA SUPPLIED:

PAYLOAD DATA  
SHUTTLE INTERFACE  
SAFETY GUIDELINES

- NASA REVIEWS AND MONITORS

STATEMENT OF WORK AND GUIDELINES  
PROGRESS

- CONSORTIA MEMBERS

<u>COSMOS</u>		<u>STAR</u>		<u>MESH</u>	
MBB	- GERMANY	BAC	- U.K.	ERNO	- GERMANY
SNIAS	- FRANCE	THOMSON-CSF	- FRANCE	MATRA	- FRANCE
MSDS	- U.K.	DORNIER	- GERMANY	HSD	- U.K.
SELENIA	- ITALY	FIAR	- ITALY	FIAT	- ITALY
ETCA	- BELGIUM	MONTEDEL	- ITALY	BATELLE	- SWITZERLAND
CASA	- SPAIN	CONTRAVES	- SWITZERLAND	BELL	- BELGIUM
CIR	- SWITZERLAND			INTA	- SPAIN
GD/C	- USA			PHILIPS	- NETHERLANDS
				GD/C	- USA

Figure 3-25. European Sortie Lab Concept Definition Studies

# PRELIMINARY

ATTACHMENT I

SORTIE LAB SYSTEM UTILIZATION CHARACTERISTICS

# PRELIMINARY

## ATTACHMENT I

### SORTIE LAB SYSTEM UTILIZATION CHARACTERISTICS

#### PREFACE

Attachment I describes the utilization characteristics of one particular system concept in considerable depth, including its mission and performance characteristics, the physical and operational interfaces and the conjectural procedures that a potential user might encounter. The material in this attachment should be considered a strawman baseline of a very preliminary nature and without the benefit of either a firm shuttle design or authoritative requirements from the user community. The reader should be aware of two other points. First, the schedule presented in Figure 3-29 is now obsolete; the final design (Phase C) is now planned to start in late CY 1974 (or FY 1975). Second, the Level I Guidelines and Constraints (Attachment II) represent the most recent headquarters task force office thinking and do not include satellite delivery and retrieval as a design mission for the Sortie Lab module and/or pallet.

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## DEFINITIONS

Sortie Lab missions create a set of terms that are meaningful to the program but have various interpretations. These are some of the more basic terms utilized in this document:

Sortie Mission: A relative short duration earth orbital space mission for conducting scientific research or other space activities with systems and equipments remaining attached to the Space Shuttle.

Shuttle Vehicle: The overall Space Shuttle vehicle as configured at launch including the Orbiter and Booster elements.

Shuttle Orbiter: The Space Shuttle element that goes into orbit and houses the payload during all flight phases.

Cargo or Payload Bay: That section of the Shuttle Orbiter which is devoted to housing payloads (a 15-foot diameter by 60-foot long compartment with full length doors).

Payload: An integrated assembly for use in space that is carried within the Shuttle Orbiter cargo bay (Sortie Lab carrier, pallet carrier, experiments, other payloads, and combinations of these).

Payload Element: A major segment of a payload (experiment, other types of specific mission payload items, payload carriers, etc.).

Payload Carrier: The payload element, such as the Sortie Lab or pallet, that supports and/or houses experiments and other payload elements.

Sortie Lab: A pressurized/habitable payload carrier for accommodating diversified experiments and equipments and providing services.

Pallet: A structural platform designed as a payload carrier for payload elements that do not require pressurized accommodation.

Experiment: That part of a payload devoted exclusively to investigating scientific or engineering phenomenon or conditions in a specific area or discipline.

Ground Operations: Payload operations that receive flight ready payload elements and process them to a launch ready condition, and after return from space, prepares them for reuse or disposition.

Launch Operations: Those operations that begin when a checked out payload is delivered to the launch area and progresses through launch activities until space/mission operations takes over.

Space/Mission Operations: Operations that take over from launch through on-orbit flight and to landing operations.

#### LIST OF ABBREVIATIONS

C&D	Control and Display
CRT	Cathode Ray Tube
CV 990	Convair 990 Aircraft (Sortie Simulation Flights)
CVT	Concept Verification Testing
DCCU	Digital Control Combiner Unit
DMS	Data Management System
ECLS	Environmental Control and Life Support System
EVA	Extra Vehicular Activity
FFG	Flexible Format Generator
GSE	Ground Support Equipment
MFD	Multi-function Displays
MPE	Mission Peculiar Equipment
MSFN	Manned Space Flight Network
OMS	Orbit Maneuvering System (Orbiter)
PI	Principal Investigator
RAM	Research and Applications Module
RAV	Remote Acquisition Unit
SLE	Sortie Lab Equipment
STE	Supporting Test Equipment
TBD	To Be Determined



## 1.0 INTRODUCTION

This preliminary document has been developed to assist in communicating the Sortie Lab system hardware and operational characteristics and user requirements as planned for a new class of space missions — the Space Shuttle sortie missions. It is intended that the material will be of value to the potential participants in sortie mission for planning the integration and operation of experiments and other type payloads elements applicable to sortie missions.

The Sortie Lab (Figure 3-26), a pressurized and habitable Lab for flight on Shuttle sortie missions, is in preliminary planning as a system to provide the initial post-Skylab manned earth orbital research and applications facility. The project is planned to include a basic Lab, a payload pallet, and several pieces of special purpose equipment. The Lab is to be a simple, versatile, and economical laboratory and observatory facility consistent with the overall Shuttle program low cost objectives. The system concept is designed to provide efficient short duration (7 days initially) space operation in various earth orbits to a broad spectrum of users in the form of special purpose scientific laboratories, carry-on multi-discipline



Figure 3-26

experiment flights, spacecraft service flights, and selected special purpose operations. Capability is available for pressurized habitable volume with direct man involvement and for unpressurized mounting of experiments or other payloads.

The sortie mode will provide a major new way of doing space research; and will extend research and applications in many areas such as Astronomy, Space Physics, Earth Observations, Communications and Navigation, Life Sciences, Material Science and Manufacturing, and Advanced Technology. The Sortie Lab and Shuttle will allow scientific and engineering research which is economical, timely, and flexible. Substantial user involvement is planned throughout the program to obtain effective and reliable payload operations. This will include participation in requirements development, facilities definition, experimental integration and operation activities, and all aspects of the operational system.

To acquaint the potential user with the planned concept, material is sequentially developed to provide an understanding of the sortie mission hardware concepts, relationships, applications, and availability; the general process of involvement and associated requirements; and finally an amplification on the characteristics of the planned hardware and operations.

This document will undergo periodic updating as the system definitions progress. Questions or comments relative to the current preliminary material should be addressed to:

Sortie Lab Manager  
Program Development  
George C. Marshall Space Flight Center  
Marshall Space Flight Center, Alabama 35812

## 2.0 SORTIE LAB FACILITY — SYSTEM AND MISSION CONCEPT

### 2.1 BASIC SYSTEM CONCEPT

The Sortie Lab complete system of flight type payload carriers and support equipment includes a twenty-six foot pressurized/habitable Lab, a sixteen foot (short Lab) version of the same Lab, a modular pallet for unpressurized payload operations, and several types of special purpose ancillary equipment. Standard subsystem provisions and interfaces are included with each element. The basic Lab with its complement of standard equipment is shown in Figure 3-27. The Lab provides considerable

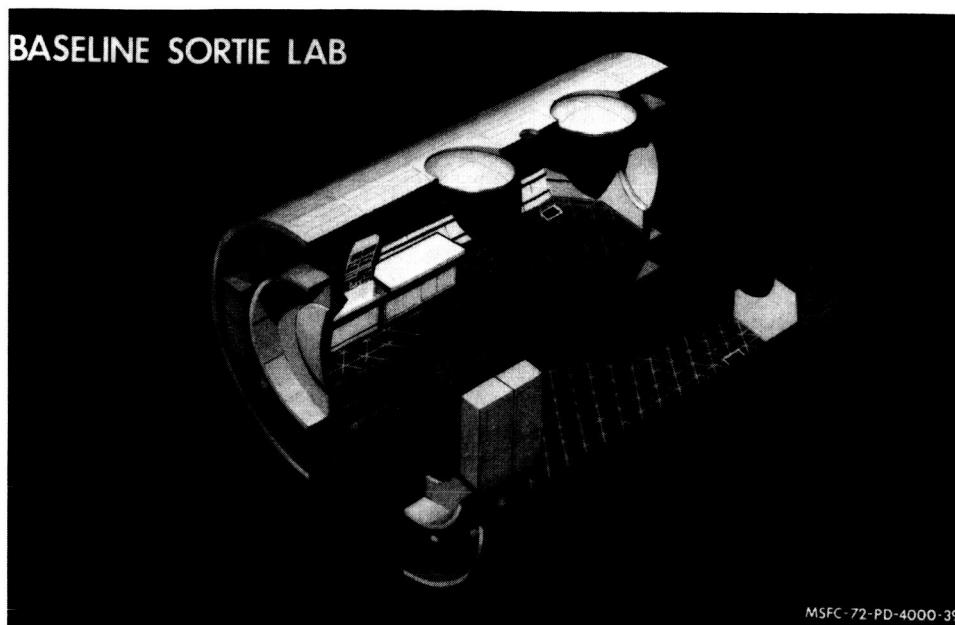


Figure 3-27

space and support equipment for internal accommodation of various experiments and experiment support equipment, provides resources such as power and data management to the experimenter, and is designed for crew habitation while operating on-orbit to allow close interaction with experiments. For selected missions the short module may be more effective. For mounting of sizeable experiments in vacuum or general payload delivery, the pallet may be utilized. The pallet is designed to be variable length and will attach to the end of either Lab or directly to the Shuttle.

## 2.2 GENERAL MISSION CHARACTERISTICS

Sortie Lab missions will nominally be performed over a seven-day period in low earth orbit at altitudes between 100 and 235 nautical miles. Higher orbit altitudes are attainable with the addition of Shuttle orbit maneuvering system (OMS) propellant in the cargo bay which reduces payload capability (less than 65,000 pounds). All orbit inclination capability is provided. For experiments requiring longer than seven days on-orbit, the mission duration may be extended up to 30 days with requisite payload penalties. Detailed mission characteristics are presented in Section 4.0.

### 2.3 NOMINAL SHUTTLE/SORTIE LAB/EXPERIMENT OPERATIONAL RELATIONSHIP

The Space Shuttle basically serves in the sortie missions to deliver the complete payload to earth orbit, station keep on-orbit for the mission duration, provide safety monitoring and control over the payload during ascent/return, provide seating and complete habitability (sleep/eat/waste/etc.) for the crew (nominally four men and up to six for 7-day missions).

The Sortie Lab and/or pallet constitute the basic experiment carrier system and effect the composite interface with the Space Shuttle through standardized interfaces. The payload crew (nominally two available on-orbit) eats and sleeps in the Orbiter cabin and enters the Sortie Lab for direct experiment operations. Free movement back and forth is envisioned with compartments separated by a hatch and short tunnel. In the case of pallet only, the crew would nominally remain in the Orbiter cabin and operate experiment payloads from a special payload provided console located in the Orbiter cabin. An EVA airlock will be available on the Shuttle, however the location relative to the cargo bay is to be determined.

### 2.4 TYPE MISSIONS

The primary mission plans for Sortie Lab and the pallet focus around Science and Applications Missions. Current planning includes analysis of Astronomy, Earth Observations, Communications/Navigation, Space Physics, Life Sciences, Material Sciences, and Physics/Chemistry types of missions. Approaches are being considered whereby these type missions are flown as single research areas on a given flight — or grouped together into two or more research areas per flight. Individual experiments can thus be planned to fit into a facility tailored to support a particular research area or as carry-on experiments to make up a multi-discipline mission. These type missions are nominally supported by the Sortie Lab (full size or short version), the pallet, special mission support equipments such as airlocks, or combinations of these.

Another major class of missions are those involving service and delivery. This class of mission could include on-orbit maintenance and servicing of an automated payload, checkout and deployment of an automated payload, structural support to a small or large payload to be delivered, and combinations of these even including the simultaneous carrying of simple "carry-on" experiments. These service classes of missions are viewed as nominally supported by the short Sortie Lab, the pallet, general supporting equipment, or combinations of these.

## 2.5 SORTIE LAB ANCILLARY EQUIPMENT

To effectively support the type mission spectrum planned for Sortie missions, the basic Lab is designed to readily accept the addition of special equipments for particular mission buildup. Figure 3-28 reflects the concept of basic supporting equipments, some of which are built in such as the crew station consoles, some of which are standard inventory and used as required such as airlocks, and some non-inventory special purpose equipment such as stabilization platforms. These specific items are discussed in a later section, but it is planned that the Lab fit-out would be tailored for each mission to maximize effectiveness.

## 2.6 AVAILABILITY OF SYSTEM AND EQUIPMENT FOR UTILIZATION BY USER

The Sortie Lab Program is being structured with the objective of maximum user involvement and accessibility. During current preliminary definition

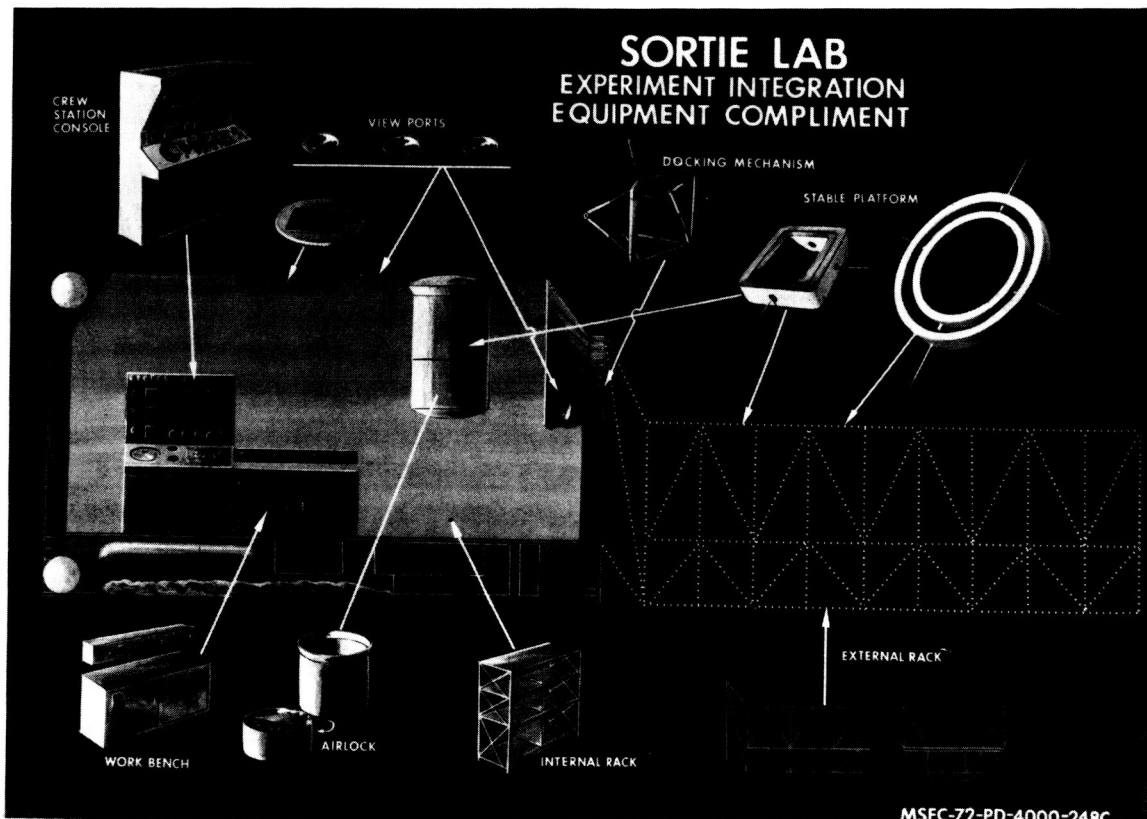
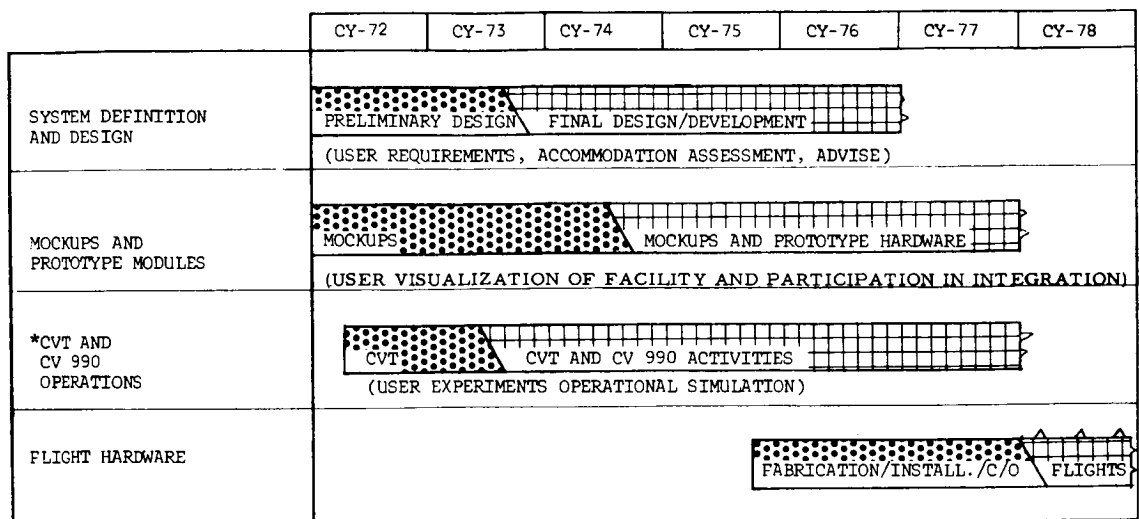


Figure 3-28



\*CVT (CONCEPT VERIFICATION TESTING) IS GROUND BASED TESTING PLANNED TO VERIFY SORTIE (AND OTHER) HARDWARE CONCEPTS, SYSTEM INTERFACE, SYSTEM OPERATIONS, AND TO SUPPORT EXPERIMENT INTEGRATION/OPERATIONAL PROCEDURES DEVELOPMENT. CV 990 (CONVAIR 990 AIRCRAFT FLIGHTS) IS AIRBORNE OPERATIONS PLANNED TO SIMULATE SELECTED SORTIE MISSIONS (OPERATIONS AND FLOW) USING REPRESENTATIVE AND USEFUL EXPERIMENTS.

Figure 3-29. Program Planning Schedule

and subsequent definition phases, see Figure 3-29 for schedule, user involvement in requirements development and as advisory to system definition is planned and strongly encouraged. The Sortie Lab management team has firm plans to actively work with the user community to effect this involvement. Special mockups and prototype equipments are planned throughout the program to provide necessary and adequate experiment accommodation understanding and interface/operations development.

Flight hardware, as previously described, consists of two complete flight articles and selected support equipment in the early program years, however, it is planned that this complement of equipment would be augmented as appropriate to satisfy approved program needs. From this equipment inventory, any user may consider the possibilities of applying on any given flight the complete Lab facilities and all supplementary equipment for his use or the user might consider being flown in combination with other experiments and utilizing only a small portion of the Lab, and/or pallet and little or no special purpose equipment. The specific resources (power, data, etc.) provided to the experimenter are discussed in subsequent sections and these may be utilized to any degree appropriate by the experimenter with proper adherence to the standardized interfaces defined and procedures to be set forth. Considerable flexibility in equipment and

mission structuring thus exists to facilitate the user in effective mission operations.

The experiment facilities which will integrate into the Sortie Lab are varied. Interfaces will be kept simple in order that equipment from one flight can quickly be replaced with different equipment for another flight. Astronomy observatory facilities flown on the pallet for one mission may be replaced in total by earth viewing sensors for a subsequent mission; or inside the Lab a Physics and Chemistry Laboratory may be stripped and replaced by a facility to perform Life Sciences experiments.

The planning schedule for the Sortie Lab systems is shown in Figure 3-29.

### 3.0 TENTATIVE USER INTERFACE AND REQUIREMENTS

#### 3.1 FLIGHT OPPORTUNITIES

To accomplish a new mode of space operations embodying low cost, limited lead-time for experiment development, and added control by the researcher the sortie mission will support frequent orbital flights with opportunities available to many scientists. Opportunity will exist for research scientists in orbit, flight of inexpensive experiments, with minimal red tape and delays, and flexible and repeatable operations.

In addition to these thrusts toward science and research, the system will support frequent piggy-back delivery of other payload elements and service missions designed to enhance automated spacecraft lifetime and effectiveness.

Flight schedules are to be determined, however, preliminary planning is allowing for several flights per year of the Sortie Lab systems with specific system and scheduling buildup to be commensurate with needs and requirements.

#### 3.2 REPRESENTATIVE PROCEDURES

The Sortie Lab experiment approval cycles will be kept simple so that researchers can apply their best efforts to research. The flow from experiment concepts to flight (Figure 3-30) envisions a streamlined process. The selection process will require a few months. The development cycle from there until integration into the flight unit Sortie Lab will vary from a few months to a few years, depending on the complexity of the experiment.

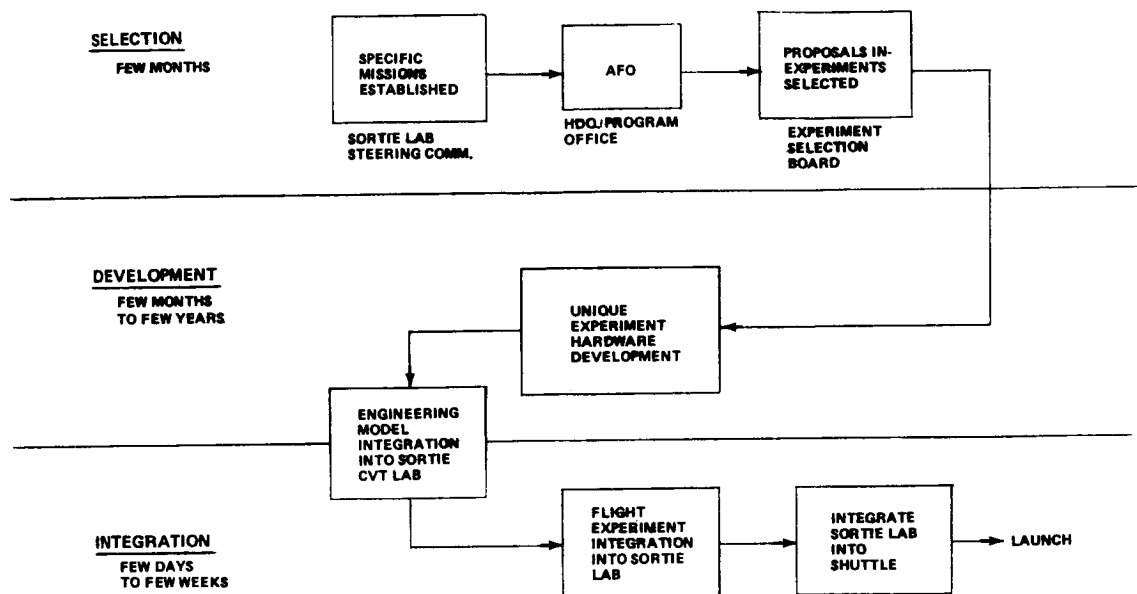


Figure 3-30. Sortie Lab Experiment Selection, Development, and Integration (Representative)

Final integration of a new experiment will require a matter of days, weeks, or months, depending on the complexity of the experiment. This time will be minimized by simple experiment/module interface design.

Unique hardware for a particular experiment would be envisioned as developed by the researcher, with management interface from an appropriate NASA Center. The basic facilities for a specific discipline laboratory or observatory would be developed by NASA and available to the researchers on numerous repeat missions. These specialized facilities will be designed with close consultation with the scientific community. Once these basic capabilities are established, they will be documented and provided as supplements to this material. Upon return from a mission, the PI will have his unique experiment hardware for follow-up testing, calibration, etc., and he may propose for reflight on another mission. The entire procedure is designed with the idea of simplified selection process, quick development, and rapid dispersal of data.

Service flights and delivery flights will be handled with a comparable philosophy of minimizing documentation and lead times will follow a similar flow path. It is envisioned, however, that the planning and approval cycles will involve only the effected Program Office and can then be planned and accomplished in a very efficient and timely manner.



### 3.3 PROPOSALS (TENTATIVE)

#### 3.3.1 Submission

Once schedules and planning have progressed and begun to firm, requests for flight of a Sortie Lab experiment or other type payload would be submitted in the form of a proposal to NASA in care of the cognizant Program Office(s).

#### 3.3.2 Contents

Proposals are envisioned as being brief, consistent with completeness. The following items should be covered.

##### 3.3.2.1 Technical

- a. Scientific or mission objectives: present state of knowledge, what can be gained from orbital flight via the Sortie Lab and interest or applications of results to science or engineering.
- b. Techniques: approach, instrumentation and accuracy, data reduction.
- c. Operational Concepts: flight times, locations, profiles.
- d. Equipment: size, weight, power, photograph equipment, and location requirements.
- e. Logistics: spares, maintenance concepts, etc.
- f. Special needs: windows, stabilized platforms, temperature restrictions, ground equipment, "g" level allowable, orientation, airlocks, etc.

##### 3.3.2.2 Management

This material would contain the names, titles, and addresses of the Project Director, or Principal and Co-Investigators as appropriate. Brief resumes may be helpful in some cases. Organization and the functions of individuals should be given in cases where the proposal covers a coordinated program, e.g., several experiments or systems from different organizational elements. A cost proposal should be submitted if financial support from

NASA is desired. A development and availability schedule plan should also be provided.

Details of what NASA can furnish in terms of auxiliary equipment aboard the Sortie Lab can be found in subsequent section of this document. Costs associated with flight operations and logistics are to be established. In general, the experimenter or other payload system manager would be responsible for the design, stress analysis, construction, shipping, and safety qualifications of his equipment, while NASA provides engineering advice during payload development and then is responsible for experiment integration into the Sortie Lab.

### 3.3.3 Proposal Review and Scheduling

Proposals would be reviewed by the cognizant NASA Headquarters Program Office and/or by a Sortie Lab Steering Committee as determined appropriate, depending on the type mission and these organizational makeups. Broad scheduling is done when agreement is reached that the mission should be flown and assurance of funding is obtained from the Program Office. Detailed scheduling would be done subsequently by the involved Project Offices.

## 3.4 RESPONSIBILITIES

### 3.4.1 General

Planning is in process to establish responsibilities and procedures for all phases of the operational program including the development time-frame, the ground operations, the flight operations and post mission support. These approaches will be made available as they develop; however, some general aspects of a typical ground operation are provided in the subsequent paragraphs.

### 3.4.2 Scheduling for Ground Operations

Ground operations, by necessity, must be responsive to schedules as it relates to mission planning, payload carrier hardware availability and the ability to turn around payload element hardware in preparation for subsequent missions. Any user of the Space Shuttle system must be well aware of the impact his experiment/carrier module has on overall scheduling and planning.

### 3.4.3 Ground Operations Flow

Ground operations for Sortie Lab payloads are very analogous to those in existence on other programs. The major difference involves a capability to receive a returned Sortie Lab payload from its mission and rapidly prepare the carrier hardware and/or the other payload element hardware for reuse on subsequent missions. Figure 3-31 recognizes the sequence of events that the Sortie Lab payload experiences as it moves through a complete ground operation cycle. For the most part, the events are self descriptive and are not discussed in detail; it must be understood that a user would furnish procedures and specifications for his experiment and work closely with the NASA during these operations.

Although ground operations primarily involves the main activity effort, as shown in Figure 3-31, it also includes several supporting functions to achieve complete results. These functions include the GSE, tooling, STE and logistics.

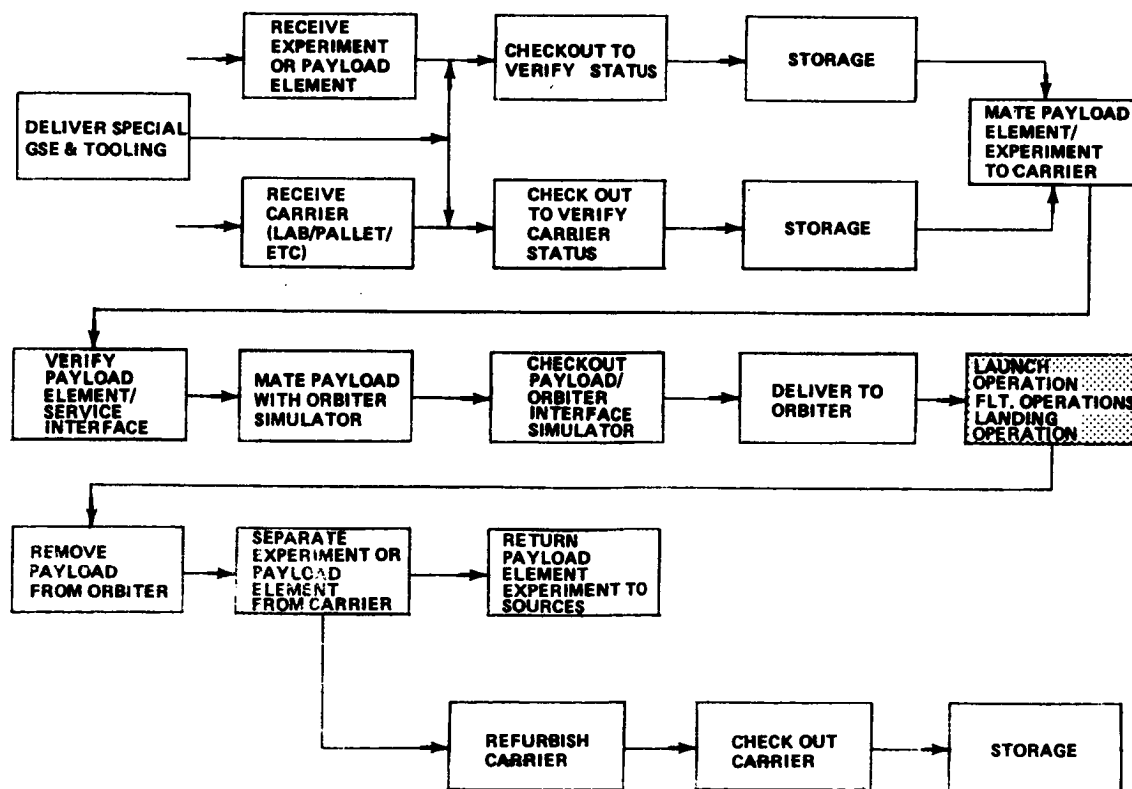


Figure 3-31. Sortie Lab Ground Operations

#### 3.4.4 Ground Operations Responsibility

The ground operations responsibility with which a user must contend is not as critical as some of those that control experiment design. However, those responsibilities do involve both the user and the NASA and should be understood during this phase of the program. Tables 3-1 thru 3-3 identify representative responsibilities assigned to the various user and NASA.

Table 3-1

##### General

User Responsibilities	NASA Center Responsibilities
<ol style="list-style-type: none"><li>1. A procedure for handling his payload element or experiment will be made available to payload center.</li><li>2. The payload element or experiment will be delivered to payload center in accordance with schedule.</li><li>3. Transportation of the payload element to and from the payload center will be a user responsibility unless special transportation is requested.</li></ol>	<ol style="list-style-type: none"><li>1. A routine ground operations handling procedure will be made available to user.</li><li>2. Upon request, special transportation will be furnished by NASA.</li><li>3. NASA will be responsible for training crewmen with the assistance of the user.</li><li>4. NASA will furnish all facilities and equipment during ground operations except for special tooling, GSE and STE that is available from user.</li></ol>

Table 3-2  
Responsibility Summary

Prelaunch	
User Responsibilities	NASA Center Responsibilities
<ol style="list-style-type: none"> <li>1. Tooling, GSE, and STE used during experiment development will be made available to payload center.</li> <li>2. Space parts for the experiment will be furnished by the user.</li> <li>3. Training assistance will be furnished by the user.</li> </ol>	<ol style="list-style-type: none"> <li>1. Basic standard facilities and equipment required for pre-launch operations will be furnished by the NASA except for certain development tooling, GSE and STE.</li> <li>2. The NASA will have certain environmental testing and verification devices, such as CVT facilities, available to the user.</li> <li>3. The NASA will meet the experiment control procedure (temperature, cleanliness, vibration, etc.)</li> <li>4. The Sortie Lab and its supporting requirements will be furnished by the NASA.</li> <li>5. NASA will provide payload training for the crewmen with the assistance of the user.</li> </ol>

Table 3-3  
Responsibility Summary

Post Launch	
User Responsibilities	NASA Center Responsibilities
<ol style="list-style-type: none"> <li>1. The user will furnish consultation service to payload center in removing sensitive data, hardware or experiment elements at landing site.</li> <li>2. The user will furnish consultation service to payload center for post flight inspection of payload and experiment hardware.</li> </ol>	<ol style="list-style-type: none"> <li>2. The NASA will be responsible for removing sensitive data, hardware or experiment elements from payload at landing site.</li> <li>2. The NASA will furnish manpower, standard facilities and equipment for disassembly of payload.</li> <li>3. The NASA will disposition Sortie Lab for reuse.</li> </ol>

#### 4.0 MISSION CHARACTERISTICS

##### 4.1 GENERAL

The Sortie Lab, Payload Pallet, and special purpose equipments are designed to be flown to various low earth orbits in the Space Shuttle cargo bay. The system would remain attached to the Shuttle (nominally in the bay with the bay doors open with the capability for deployment out of the bay if required) for operations throughout the mission duration. Station keeping on-orbit and basic directional pointing and orientation is provided by the Space Shuttle. The Lab and its experiments are monitored relative to basic safety aspects during launch from a payload console inside the Orbiter cabin and once on-orbit the payload crew may enter the Sortie Lab to commence operations.

##### 4.2 ORBITS AND PAYLOAD

The Sortie Lab and systems will operate attached to the Shuttle in an orbit which will be preselected based on mission requirements. From the KSC

launch site, orbits of 28.5° to 55° inclination may be achieved at altitudes of 100 n. mi. to several hundred nautical miles (depending on the tradeoff of payload and Shuttle orbit maneuvering propellant). For polar (90° inclination) and near polar orbits the Western Launch Range will be utilized. An approximate payload capability to various orbit altitudes at 28.5°, 55°, and 90° inclinations is shown in Figure 3-32.

For planning, assume 80% of basic payload capability and subtract the weights of the basic carrier elements and equipment to determine the maximum experiment complement, the weight available for delivery of automated spacecraft, the weight available to service missions, or to other type payloads. For planning purposes the total weights of the major carrier elements are estimated to be: basic Sortie Lab with systems — 12,000 pounds, short Sortie Lab with systems — 9,500 pounds, and a 30-foot length pallet — 1,200 pounds. As an example assume a standard Sortie Lab with a 30-foot pallet going to a 100 n. mi. by 28.5° inclination orbit. The payload available to experiments or other type payloads would be 65,000 pounds times 0.8 less 13,200 pounds, or 38,800 pounds.

#### 4.3 MISSION DURATION

The nominal time from Shuttle lift-off until Orbiter return is seven days. This gives approximately 6.5 days for on-orbit operations with Sortie Lab and Orbiter since time for checkout and maneuvering for the vehicle must be considered. Shorter duration missions may be accommodated, if desired. Longer duration missions, up to 30 days, are planned to evolve as the program and requirements indicate.

It may, for example, be desirable for certain scientific missions to maximize the time spent in the earth's shadow. The 100-nautical-mile orbit at 28.5-degree inclination provides a maximum of 37.4 minutes dark time per orbit. This compares to a maximum of 35.8 minutes dark time for a 400-nautical-mile orbit at the same inclination.

#### 4.4 MISSION TRACKING COVERAGE TIME

Tracking data from the Manned Space Flight Network (MSFN) is summarized in Table 3-4. It should be noted that for the 400-nautical-mile summary, only six MSFN stations are utilized whereas in the 100-nautical-mile and 270-nautical-mile altitudes seven MSFN stations are used. It is shown in the table that the higher altitudes give more contact time as well as increasing the number of contacts. Only contact times of 5 minutes or more are counted in this data tabulation. Also, when multi-coverage

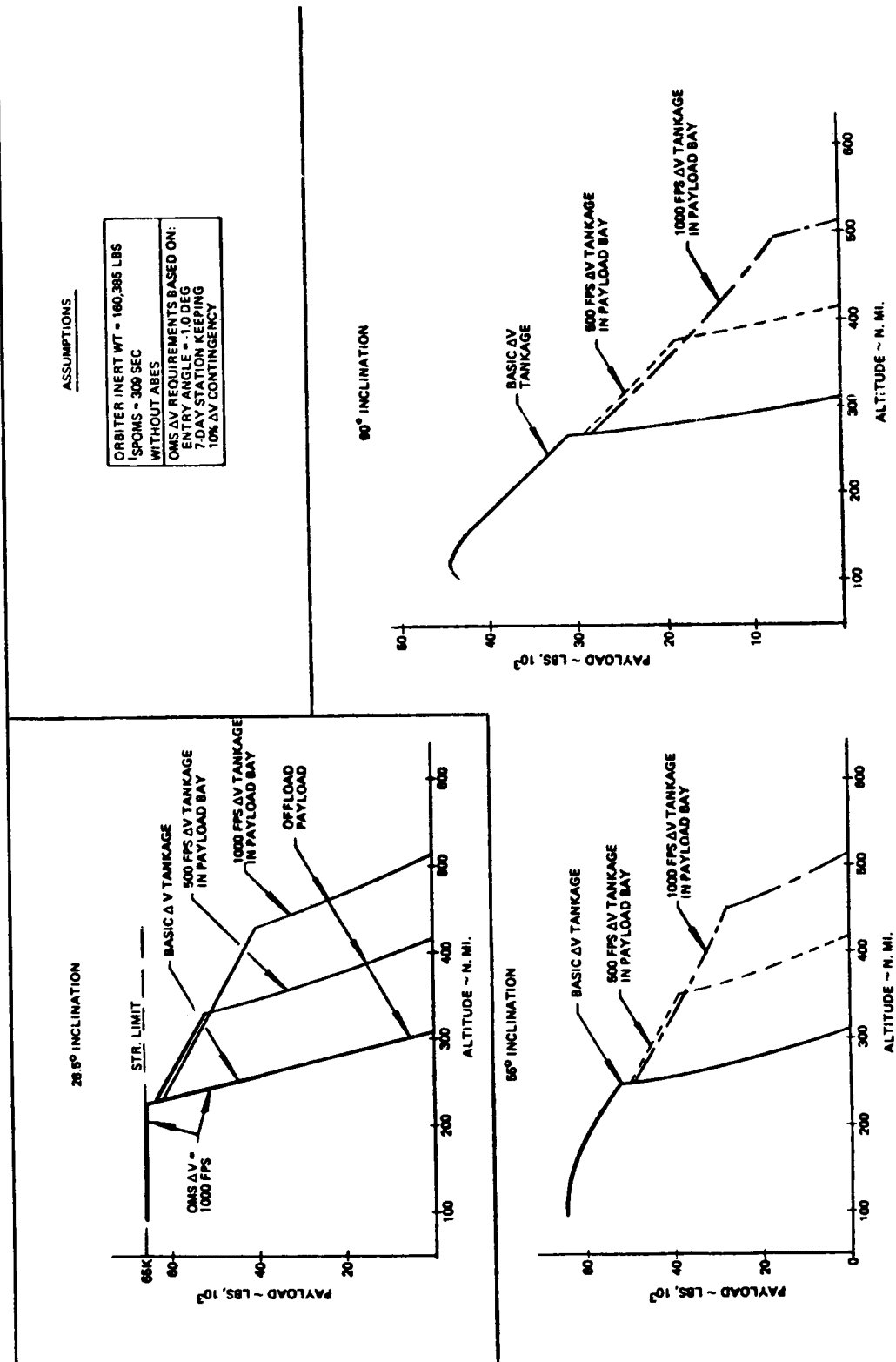


Figure 3-32. Payload Weight Limits Based on Estimated Shuttle Capabilities



Table 3-4  
MSFN Coverage Summary

Tracking Data	Orbital Count = 70 Revs / Inclination = 28.5 Degs		
	100 N. Mi. Altitude 7 Stations	270 N. Mi. Altitude 7 Stations	400 N. Mi. Altitude 6 Stations
Total Contact Time (70 Revs) (Min)	586.73	2059.53	2463.45
No. of Contacts (70 Revs)	98	208	195
Percent of Contact Time (70 Revs)	8.94	28.98	32.80
Average of Contact Time Per Rev (Min)	8.38	29.27	35.19
Average No. of Contact Per Day	22	42	37
No. of Revs Without Contact	5	0	0

occurs, that is, more than one station in contact with the satellite at the same time, the station with the lesser time is eliminated from this data tabulation. During the specified contact times it would be possible to effect real time communications within the limitations of the communication system provisions as specified in a later section.

#### 4.5 MISSION TYPES

##### 4.5.1 Science and Applications Missions

Two major reasons exist for research experiments in orbital space flight. One is for an observation platform with an unobstructed view of space or earth. The second is to use the unique environment of space such as zero-gravity and unlimited vacuum.

This natural division dictates the type of missions and support which will be provided by the Sortie Lab.

Those experiment areas that are primarily interested in an observational platform include Astronomy, Earth Observations, Communications/Navigation, and Space Physics. They are ideally suited to an external mounting rack which provides an unobstructed view while the other disciplines like Life Sciences, Materials Sciences, and Physics and Chemistry (primarily interested in zero-gravity effects and needing direct interface with man) required a pressurized laboratory.

Missions now planned (which include all of the above types) for the Sortie Lab are based on the assumption that only two scientists/researchers will be on each sortie flight. Because of timeline limitations and the limited knowledge of any two experimenters, the early missions will largely be limited to one or two major research areas per flight.

#### 4.5.2 Service and Delivery Missions

One major category of missions for the Sortie Lab or pallet will be to provide support for the qualification testing of sophisticated space hardware, for the service and maintenance of large automated satellites, for the delivery support of large payloads (pallet), and for piggy back delivery of small payloads. Small piggy back type payloads may be able to fly with planned research or servicing type missions at very low (shared) delivery costs. In like manner the potential exists to carry on small sortie experiments during planned servicing or delivery missions, also at a low cost to those experiments. The Sortie Lab for the service applications may be the short version to allow sufficient room in the cargo bay to carry the equipment being delivered or tested, and in the event a satellite being serviced cannot be repaired, it can be returned to earth for complete refurbishment.

A typical Shuttle/Sortie Lab service and delivery mission might be:

- Deliver, checkout, and release payload
- Change orbits
- Repair and resupply an automated satellite on-orbit

- Change orbits again
- Rendezvous with, retrieve, and return to earth a satellite ready for major refurbishment

One Shuttle flight, with the properly equipped Sortie Lab will accomplish all this plus perform small simple "carry-on" experiments as capabilities allow, thereby getting maximum utilization of each flight.

#### 4.5.2.1 Test Control Center Application

One major benefit of the Shuttle transportation system will be the testing of hardware in the space environment. The Sortie Lab systems will allow accommodation and flight of developmental and test type equipment for short duration flights with reasonable costs. Confidence that sufficient reliability has been achieved can be demonstrated more readily and effectively than months of ground testing. The testing and development of components for experiments and subsystems will be secondary on many missions and will share proportionately in the flight costs. Such tests will utilize the modest margin in Sortie Lab payload weight, power, and astronaut time.

#### 4.5.2.2 Maintenance of Automated Satellites

One of the most important service applications of the Sortie Lab will be resupply and maintenance of automated satellites. The more complex payloads launched in the late 70's and the 80's will have provisions incorporated for on-orbit repair and servicing of experiment hardware and spacecraft subsystems. The interfaces on the service version of the Sortie Lab will be defined early to assure compatibility with the payloads to be serviced in the Shuttle era.

For servicing, the Lab or pallet will be outfitted with equipment required to check out, activate, service, repair, or modify payloads (either delivered or revisited payloads). Supplementary equipment will be provided as required to assist in deployment and retrieval of payloads. To effectively accomplish these servicing missions, the sortie mission hardware will handle the expendables, spare parts, utility requirements, and operational techniques which are associated with the servicing missions.

#### 4.5.2.3 Delivery and Checkout

Payloads for this type mission are varied from small Explorer-class satellites to free-flying RAM's to planetary and lunar probes. Some of these missions will include small injection stages or large high performance stages. These may utilize the pallet only, the Lab only, or both. The pallet would serve for system structural support of large or small payload elements, and the short or long module would provide other systems/operations support such as checkout.

The operations for the delivery of low earth orbit payloads (that is, those that do not require a kick stage) will be straight-forward. After delivery to orbit the payload may be checked out as required by equipment mounted in the Lab, on the pallet, or in the Orbiter. If satisfactory, the satellite will be deployed and left, if not, it may be repaired utilizing tools, equipment, and spares that housed in the Lab, on the pallet, or in the Shuttle. If the required repairs are not possible on-orbit, the satellite will be returned to earth via the Shuttle for the needed repair on them and relaunched later on another Shuttle flight.

### 5.0 BASIC SYSTEM DESCRIPTION

#### 5.1 BASIC SORTIE LAB FACILITY

The basic Sortie Lab (Figure 3-33) is a pressurized vessel consisting of a cylindrical portion and two removable end bulkheads that provide a habitable environment for the crew and accommodations for conducting experiments in orbit. The cylindrical portion has a structural diameter of 14 feet. The cylindrical length is 240 inches, the bulkheads on either end are 33 inches deep so that the total length is 306 inches. The Sortie Lab subsystems and general experiment support equipment occupy a portion of the forward half of the available mounting space (above and below the floor). The remaining space is available for experiment and equipment installation.

The standard Lab includes a crew station console for monitoring the operation of the module systems and for experiment operation, (separate special purpose experiment equipment may be utilized), a work bench for general operation support, standard equipment racks for carry-on electronics, and a crew system cabinet for crew personal items. The Lab

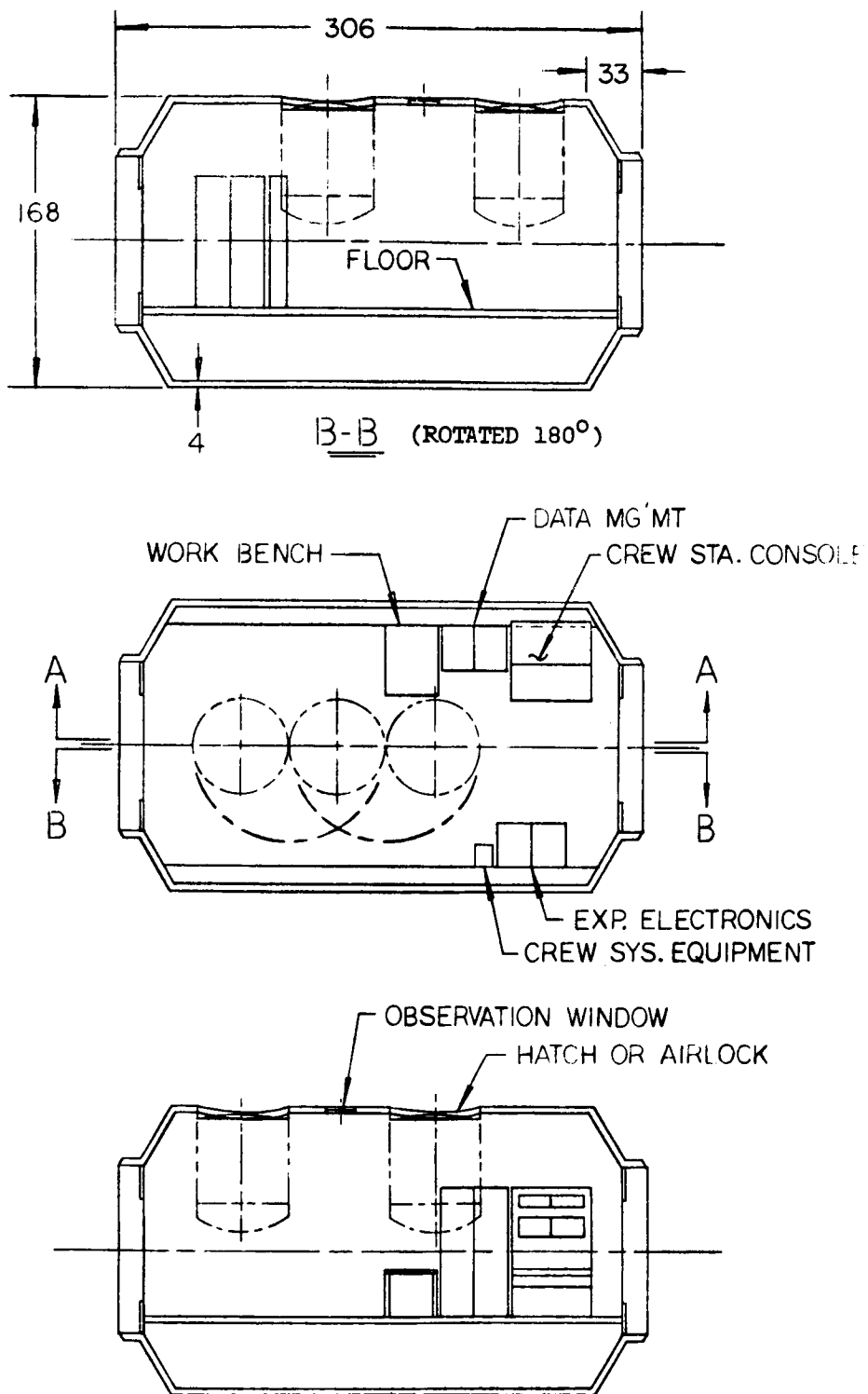


Figure 3-33. Basic Sortie Lab Interior Arrangement

design also has standard provisions for thermal control; electrical power; data management; equipment structural support; storage or accommodation space for experiments; standardized connectors for power, data, vacuum, and lighting; viewports; and structural attachment fittings for standard supplementary equipment such as experiment airlocks, large view windows, or pallets which are planned elements of the program.

In addition, the basic Sortie Lab design will be configured to accept addition oriented equipment to allow the effective accommodation of varied types of experiments or the tailoring of the Sortie Lab for specialized scientific disciplines. The mission hardware can thus be assembled to include the desired makeup of standard provision, special equipment planned and available in inventory (such as pallet or airlock) and separately provided mission equipment such as stabilized platforms.

The basic resources provided by the standard size Sortie Lab for use by experimenters is summarized in Table 3-5 below.

Table 3-5  
Lab Nominal Resources Available To Experiments

	Ascent/ Reentry	On-Orbit
Available Volume (ft <sup>3</sup> )	2000 ft <sup>3</sup>	2000 ft <sup>3</sup>
Mission Time	TBD	Up to 6.5 days (growth to longer duration)
Electrical Power (d.c.) (kW-ave/pk)	1.0/1.5	1.5 to 2.0/3.0 to 5.0
Active Thermal Control (btu/hr)	TBD	5,400
Data Recording Rate (bps)	TBD	100,000
Data Storage Capability	TBD	Mag. tapes as required
Data Transmission Rate (bps)	TBD	25,000 (S Band)
Data Computation	TBD	Up to 16k-16 bit words
Control Consoles	TBD	2 CRT and Keyboards
Crew	1-2	2 (Larger Crews Feasible)
Atmosphere Pressure (psi)	14.7	14.7
Atmospheric Temperature (°F)	75 ± 5	72 ± 5
Stability	—	TBD (See Section 9.0)

## 5.2 SHORT SORTIE LAB (Reference Table 3-5 resources, except volume).

The short Sortie Lab (Figure 3-34) is similar to the basic Sortie Lab except the cylindrical length is reduced to 10 feet. It is intended to provide crew support, checkout or servicing facilities, operation stations for unpressurized pallet mounted experiment payload elements and other payload elements. Such payload elements can be connected to and launched with the Short Sortie Lab or can be docked to it in orbit.

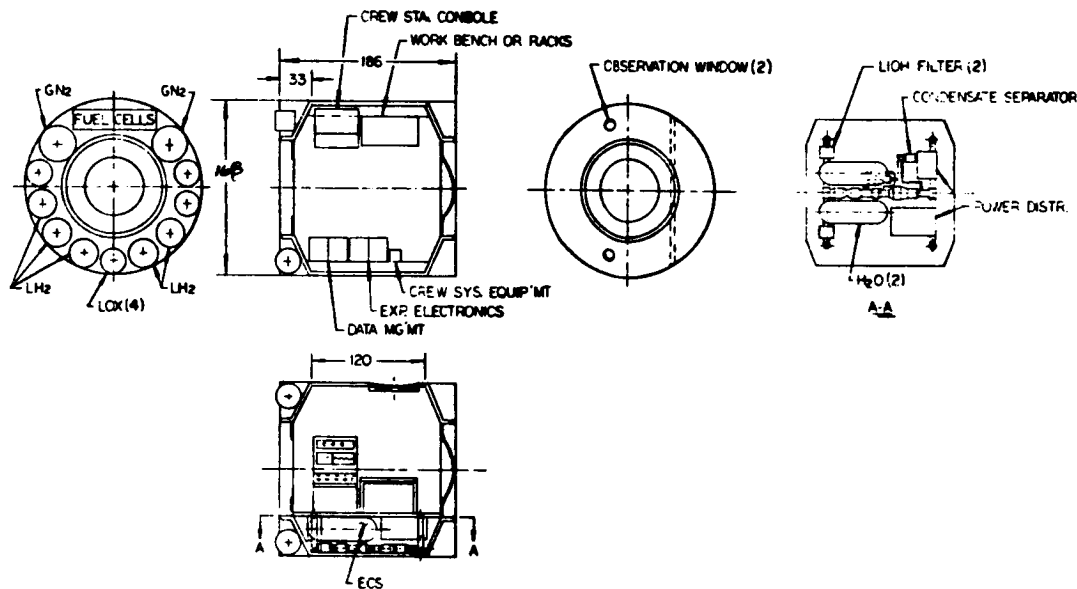


Figure 3-34. Short Sortie Lab

## 5.3 PALLET

The pallet (Figure 3-35 below) is a variable length platform on which experiments and supporting equipment are mounted and launched to orbit inside the Shuttle payload bay. The size of experiments that can be accommodated can vary from very small up to 120-inch diameter by 680 inches long. Experiments can be conducted with the pallet inside the Shuttle payload bay or with the pallet deployed 90 degrees from the payload bay. Payload elements (such as free-flying or automated spacecraft) can also be separated from the pallet for unmanned operations.

The pallet may be flown with the Lab (16-foot or 26-foot lab) or separately. Depending on the mission makeup, it may be considered for carrying

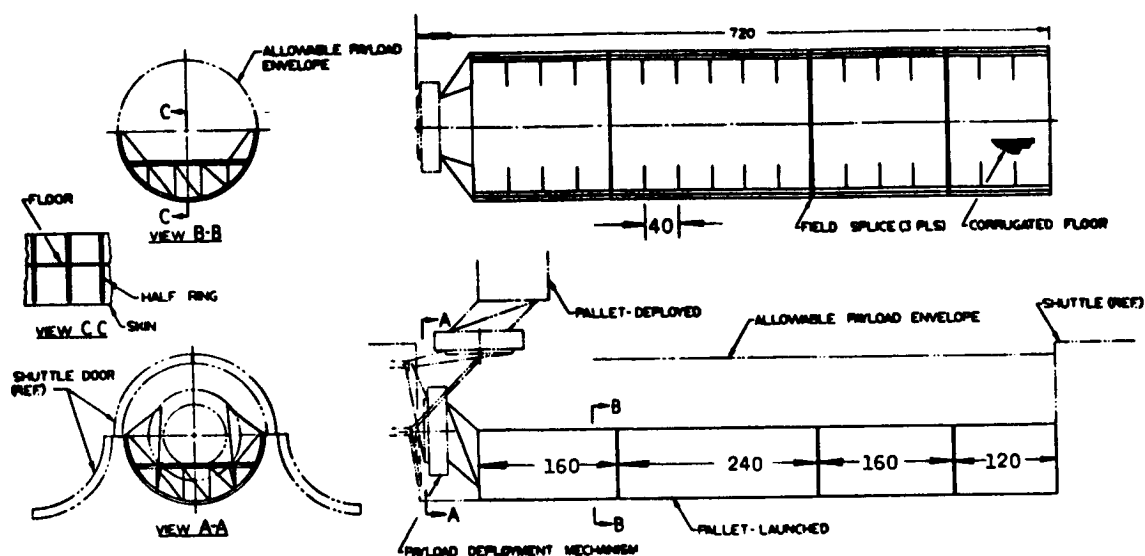


Figure 3-35. Payload Pallet (Modular-Representative Lengths)

sortie mission experiments, piggy back payloads for delivery, or complete payloads for delivery to orbit. For sortie missions the Lab would nominally be combined with the pallet (Figure 3-36) and would provide for crew and pressurized experiment support and the pallet provides for unpressurized experiment support. The unpressurized experiments are usually mounted on the pallet and remotely controlled or monitored by

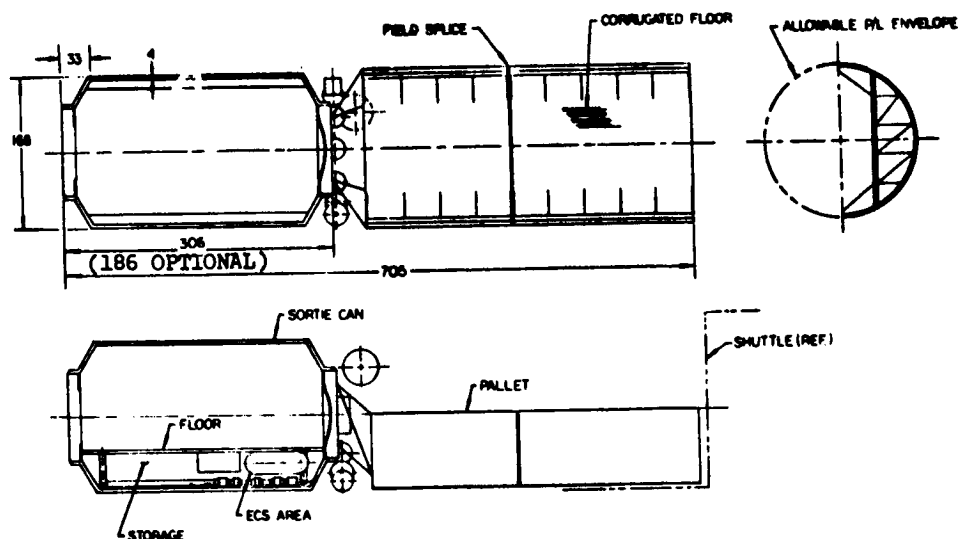


Figure 3-36. Combined Sortie Lab/Pallet



the crew inside the module. For extremely long unpressurized payloads the pallet may be flown in the bay without the Sortie Lab and monitored/controlled from payload control stations specially mounted in the Orbiter cabin.

## 5.4 SPECIAL PURPOSE EQUIPMENT

### 5.4.1 General

In addition to the basic Sortie Lab there is special purpose ancillary equipment that can be provided to build up the system as required by the mission. The ancillary equipment includes airlocks, view ports, stable platforms, crew station consoles, internal racks, work bench, docking mechanism, and miscellaneous equipment. Any or all of this equipment can be included on any given mission depending on the requirements of the mission.

### 5.4.2 Airlock (Standard Inventory)

The Sortie Lab detachable airlock (Figure 3-37 below) is intended for use in deploying experiments from the Sortie Lab to the ambient environment. The experiments can be mounted to an experiment platform that is connected to an extension or deployment mechanism (for localized deployment out of the airlock) or to a stabilized platform that is mounted on the experiment platform.

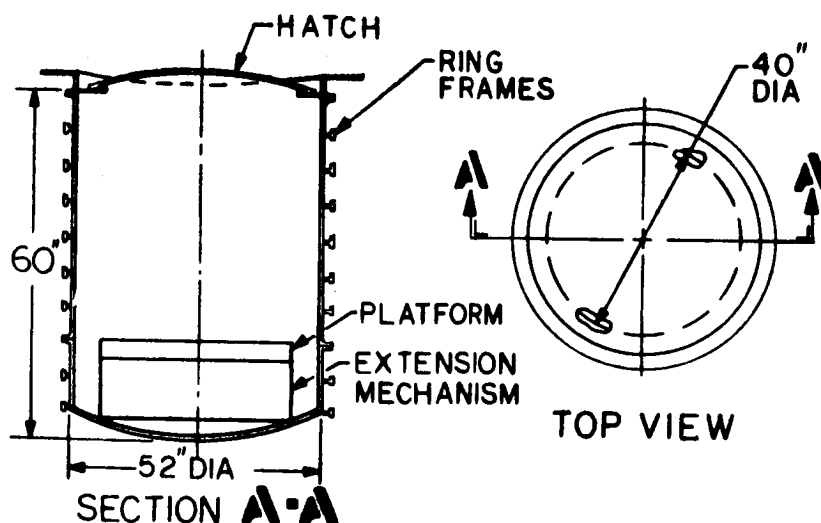


Figure 3-37. Scientific Airlock

The airlock lower door separates just forward of the experiment mounting platform. The aft section of the airlock, with the experiment platform and deployment mechanism, is moved down and rotated into the module for easy access to the platform. Experiments are mounted to the platform and the aft section is then rotated back into position and raised to connect to the forward section. The outside airlock door is opened remotely and the experiments may be extended or kept in position.

The forward airlock door opening and the experiment platform are about 40 inches in diameter. Several small experiments or one larger experiment can be attached to the platform and deployed. After completion of the experiment operation, the airlock operating procedure is reversed and the experiments may be serviced or exchanged for other experiments.

#### 5.4.3 View Ports (Standard Built In)

Three small (approximately 9-12-inch diameter) view ports are available for use in the Sortie Lab. Two of these standard view ports are located in the aft bulkhead and one is located between the experiment airlocks. These may be replaced by optical quality ports if special experiment viewing is necessary.

#### 5.4.4 Special Purpose Windows (Availability TBD)

If an airlock is not used, either of the openings may be covered by a hatch or special window. The special optical window is for experiment viewing and could have a viewing size approaching 40 inches in diameter. In addition to the window, experiment mounting points would be provided by the lab. Such experiments will be mounted to the wall or floor for launch and positioned by the crew in orbit.

#### 5.4.5 Aft Hatch Special Closure (Availability TBD)

The 60-inch diameter aft hatch can be replaced by a special structure for additional or special experiments which require both viewing and pressurized access. The experiments can either extend through an opening, if they are properly sealed, or they can operate through a window in the structural extension.

#### 5.4.6 Stable Platforms (Availability TBD)

A stable platform, as described in Section 8.0, can be provided for those experiments that require better stability or more accurate pointing than the Shuttle can provide. The stable platforms can be mounted inside the airlocks or on the pallet.

#### 5.4.7 Docking Structure (Standard Inventory)

The standard Sortie Lab is normally connected directly to the forward section of the Shuttle cargo bay with a pallet attached to the rear of the Lab. If the Sortie Lab is deployed, i.e., rotated 90 degrees out of the payload bay, it can be used for such purposes as docking to free flying satellites for servicing, etc. For that purpose, a docking mechanism (Figure 3-38) will be attached to the aft bulkhead.

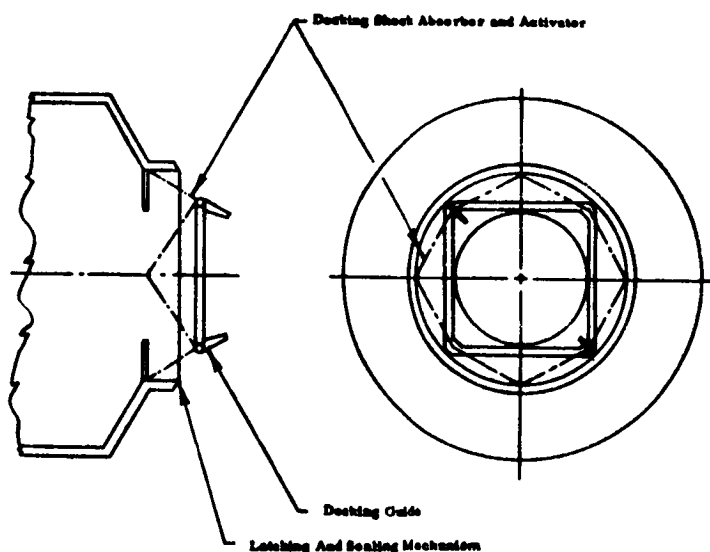


Figure 3-38. Docking Adapter Concept

#### 5.4.8 Miscellaneous Standard Equipment

Tools provided will consist of general types of tools such as used in the Skylab mission and special tools as required for Lab and experiment maintenance and operation.

Capability will be provided for minor trouble shooting or checkout of the Lab systems and flight experiments.

Spares, as determined appropriate, will be provided for minor maintenance and repair of the Lab systems and flight experiments.

Restraints such as vices and holding devices for parts to be repaired will be provided. Crew station and crew mobility restraints and aids will also be provided to allow effective crew support.

Repair manuals for the Sortie Lab systems and flight experiments will be provided as required for planned maintenance and repair.

The availability of modularized avionics equipment for carry-on use by the experiment or the payload element is TBD.

## 6.0 EQUIPMENT INSTALLATION AND CONSTRUCTION

### 6.1 GROUND ACCESS TO LAB FOR INSTALLATION

The rear bulkhead, Figure 3-39, can be removed for installation and removal of experiments and equipment. After installation of the bulkhead onto the Lab, access for checkout and maintenance is through the 60-inch diameter hatches in both bulkheads.

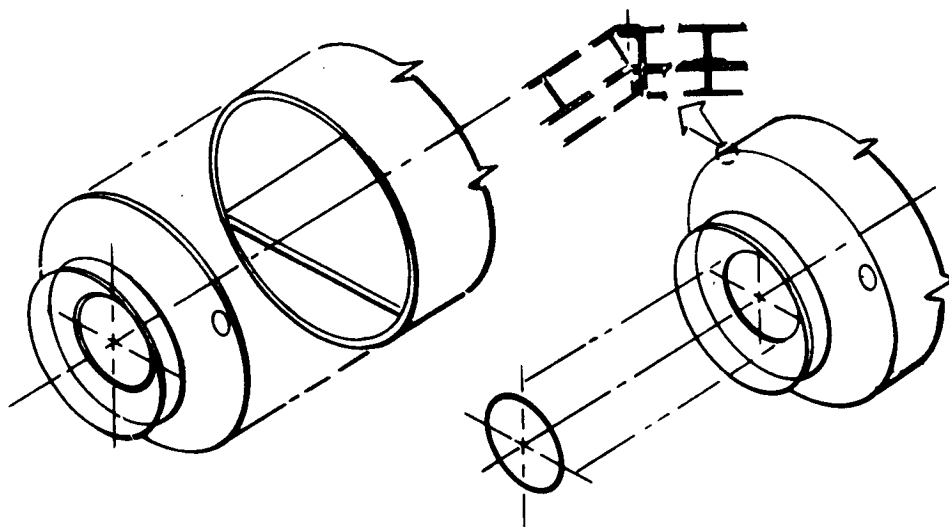


Figure 3-39. Bulkhead Removal

## 6.2 MOUNTING TECHNIQUES

There are provisions for mounting experiments on the floor, wall (longerons), equipment rack and pallet. A typical floor or wall attachment arrangement is shown in Figure 3-40. This figure also shows the equipment rack which is an integrated part of the Lab structure. Equipment is bolted into the rack.

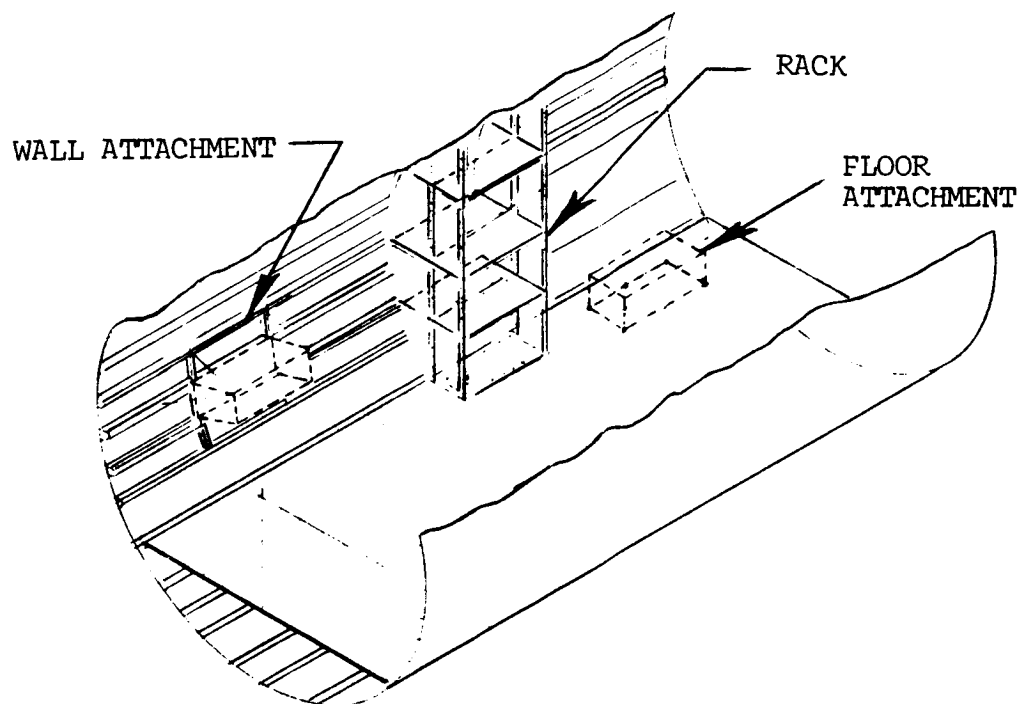


Figure 3-40. Interior Mounting

Equipment is bolted to the grid floor shown in Figure 3-41.

The wall configuration consists primarily of longerons. These longerons can be configured to accommodate various types of experiment packages. The experiments are attached to the wall as shown in Figure 3-42.

Equipment is bolted to the floor of the pallet as shown in Figure 3-43. The pallet floor is constructed of suitable panels mounted to cross beams. Experiments, piggy-back systems, or general equipment can be mounted directly to the floor, or to frames.

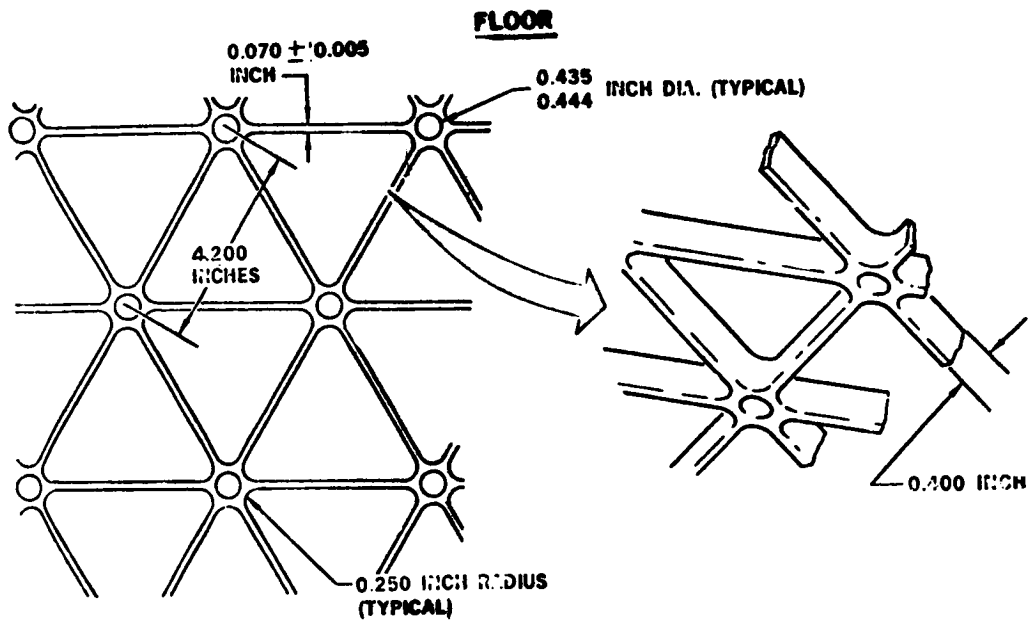


Figure 3-41. Floor Attachment

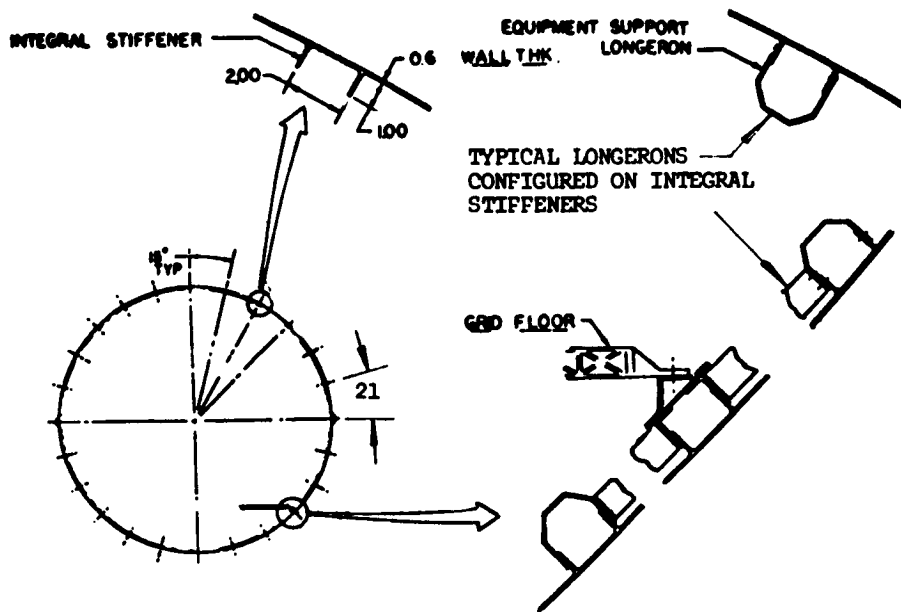


Figure 3-42. Wall Mounting

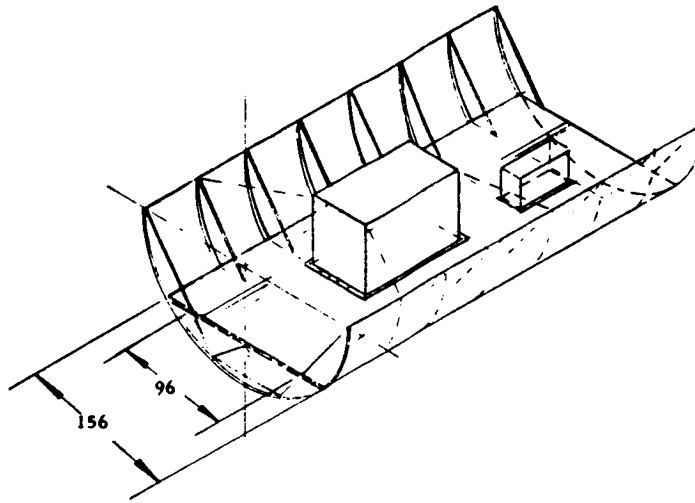


Figure 3-43. Pallet Mounting

### 6.3 CONSTRUCTION CONSTRAINTS

The experiments and their support structure must be certified to fly in the Sortie Lab/Pallet, i.e., they must be designed and in some cases tested for the Sortie Lab/Pallet flight environments. The procedure for certification of experiments and support structure that fly on the Sortie Lab/Pallet are TBD.

### 6.4 ALLOWABLE LOADS

The allowable experiment introduced loads must not exceed the local attachment capability or the overall structural capability of the Sortie Lab. The allowable loads for the four equipment attachment locations are discussed below:

- (1) The allowable loads for the floor attachments are TBD. The allowable spacing and load densities are TBD.
- (2) The allowable loads for the wall longeron attachments are TBD. Also, the allowable spacing and load/longeron is TBD.
- (3) The allowable loads for the equipment rack are TBD.
- (4) The allowable loads for the pallet are TBD and the load density is TBD.

## 6.5 LOAD FACTORS (ACCELERATIONS, VIBRATIONS, ACOUSTICS)

The experiments must withstand the flight environment inside the Sortie Lab or on the pallet.

The primary loads are the Shuttle flight (steady state) accelerations and these accelerations are given as load factors below:

$*N_x$ (g)	$N_y$ (g)	$N_z$ (g)
+3.0	$\pm 2.0$	$\pm 0.3$
-0.2	$\pm 1.0$	$\pm 2.5$
-1.0	$\pm 0.5$	-3.0

\*More comprehensive data are given in reference documents.

The vibration environment inside the Lab and on the pallet is TBD. These loads will be additive to the flight acceleration loads.

The acoustics environment the experiments see depends on the location. The acoustics inside the Lab are TBD. The acoustic level on the pallet is the same as the payload bay. (Maximum overall pressure level is 145 db.)

## 7.0 AVIONICS SYSTEMS

### 7.1 CONTROL AND DISPLAY

A control and display (C&D) console, Figure 3-44 below, will be furnished as a standard part of the Sortie Lab. The Sortie Lab C&D console will receive inputs from the data management system (DMS). It will also have the capability to display video information from experiment or other closed circuit channels. Cable trays and hardwire patch distributors will be available for use by, and under control of, the principle investigator.

The console will have the capability to operate Lab subsystems and to monitor or control certain aspects of the experiments. The console will contain a minimum of two cathode ray tubes (CRTs) as instrument pointing and data monitoring functions. The major item in the console is a multi-function display (MFD). The system has the dual capability for video display or display of electronically generated symbology. A typical MFD



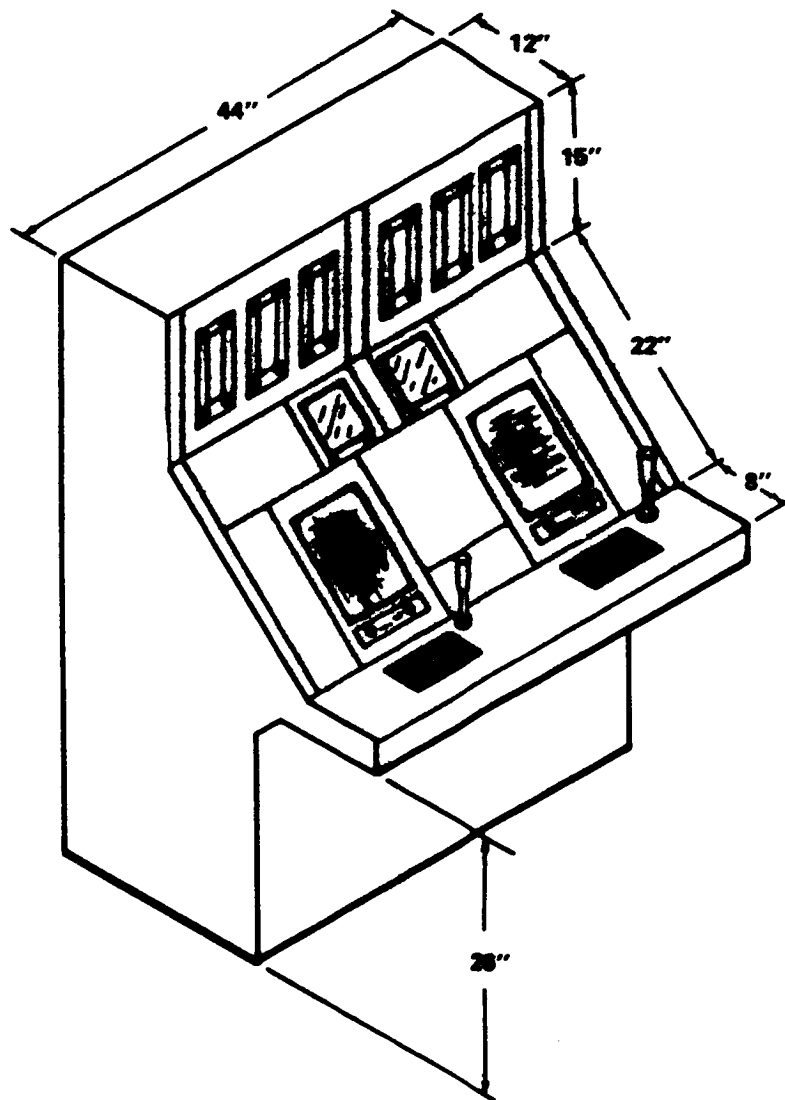


Figure 3-44. Console Concept

system is composed of a display unit, a symbol generator and a control unit. Characteristics of the system are shown in Figure 3-45.

The display unit consists of the CRT, power supplies, and the video sweep circuits as shown in the block diagram. The unit will display scales, curves, a test variable marker and a trend vector. The video display is similar to a 525 line black and white raster as in commercial TV. Video information is supplied by closed circuit vidicons located at the experiment or throughout the area. The display size is a 10-inch diagonal

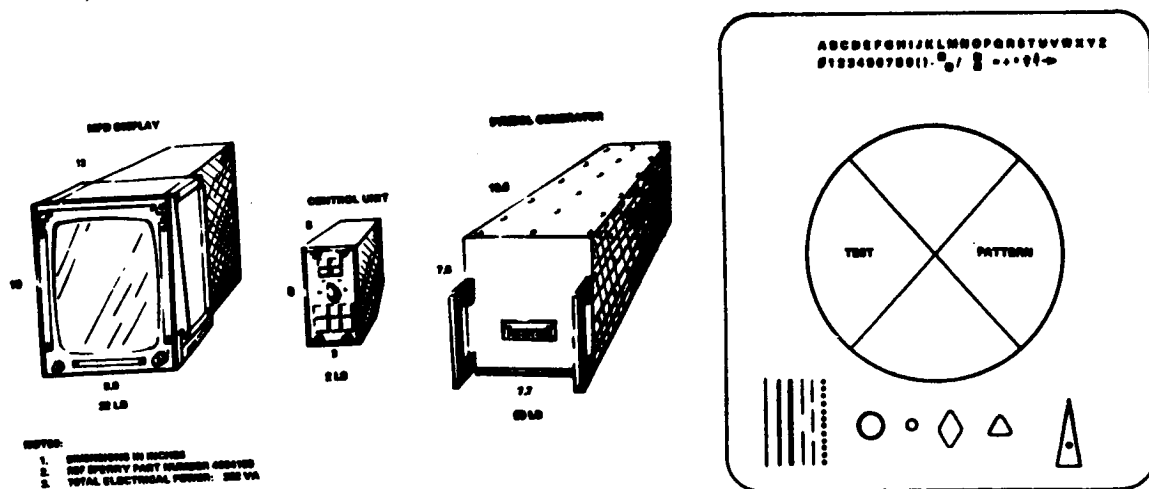
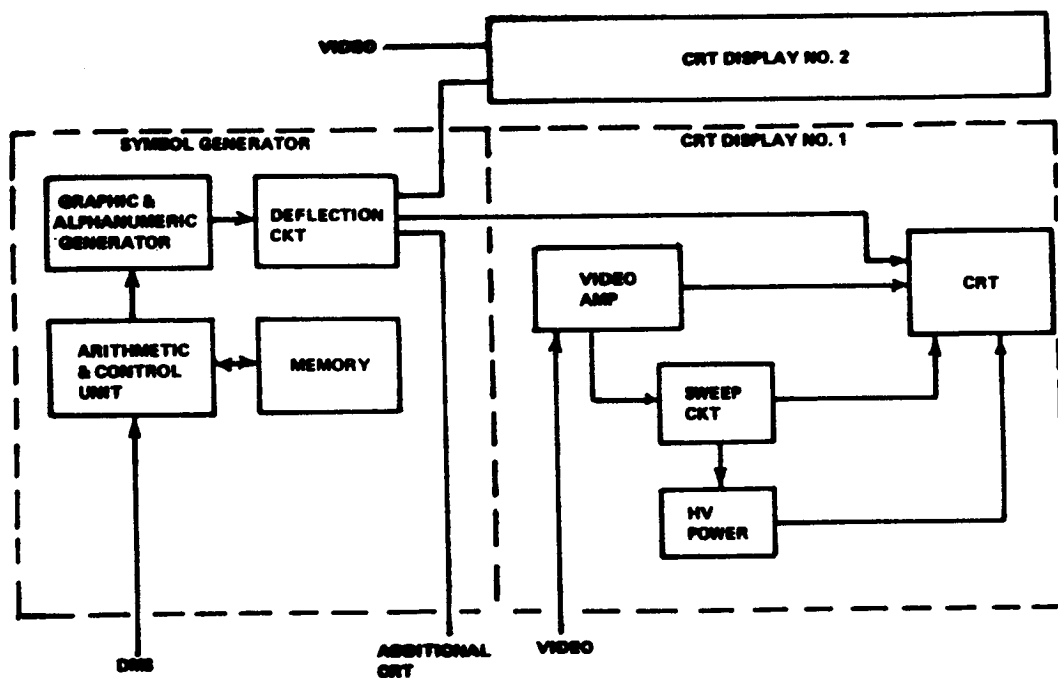


Figure 3-45. Typical MFD System

screen. Lines, scales and curves, and alphanumerics are generated by the symbol generator and can be displayed on two CRTs. The control unit allows the selection of operating mode.

Keyboards are provided for both display units. The operator requests a display of operating mode using the function keyboard. Operating modes, such as experiment operations, are displayed from which the operator makes his selection. Next the operator requests a display of modes such as automatic sequences, from which an experiment sequence could be selected. For example, a sensor might be exposed at several time intervals for a sequence of filter positions under control of the DMS.

Space will be provided in the Sortie Lab for locating experimenter controls and displays, special electronic and checkout equipment, and other mission peculiar equipment (MPE). The MPE will interface with Sortie Lab equipment (SLE) for caution and warning or other special hardwire control through a SLE patch distributor.

Caution and warning or other special hardwire functions will be routed to the mission specialist station in the Orbiter via hardwire. Some of these functions may be utilized at the mission specialist station and some will be routed to the flight crew station for caution and warning.

## 7.2 DATA ACQUISITION

The data acquisition system, see Figure 3-46, uses a two wire party line approach to gather data from remote points. The highest system bit rate is 102.4 Kbps. Experiments requiring higher bit rates or analog data will be hardwired directly to the magnetic tape recorders or computer input/output. The principal components of the system are the Remote Acquisition Unit (RAU), Flexible Format Generator (FFG), and Digital Control Combiner Unit (DCCU).

Remote Acquisition Unit (RAU) — Each RAU contains addressable analog and bi-level multiplexers, and an analog-to-digital converter. The number of RAUs in any system configuration is selectable from one to sixteen. Each RAU will sample a maximum of 64 analog (0 to +5.0 volt inputs) and 64 bi-level (0 to +10.0 volt input with 3.0 volt switching point) signals. The experiment or experiment equipment can connect to the RAUs by providing signal conditioners to convert the output of the experiment sensors to these voltage levels. The maximum sampling rate is 12,800 samples/sec.

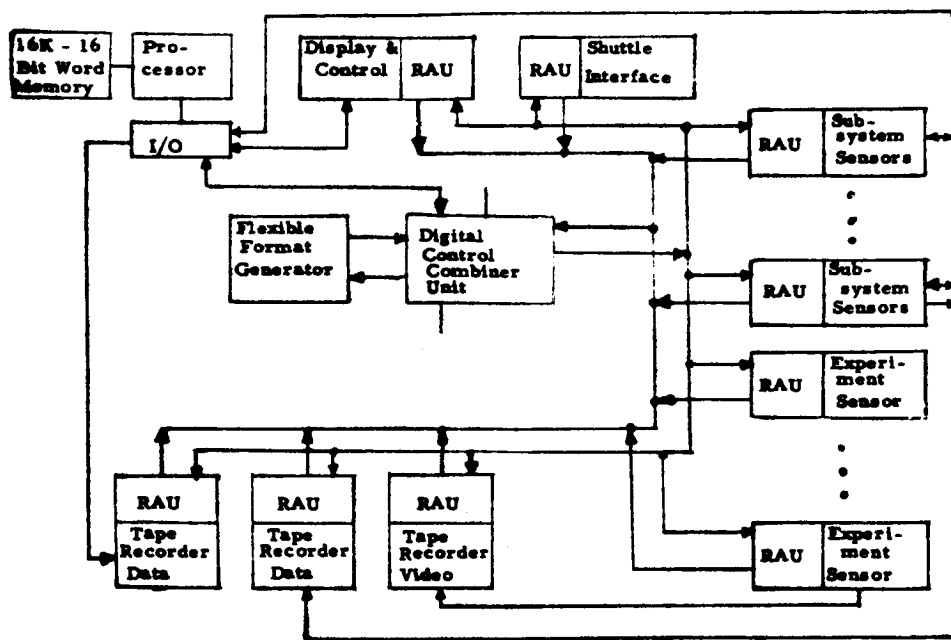


Figure 3-46. DM Block Diagram

The Flexible Format Generator (FFG) — Provides the channel address and format synchronization data. It operates as an extension of the DCCU and interfaces only with the DCCU. The FFG is basically a memory in which channel addresses, data, and format control instructions are stored.

The Digital Control Combiner Unit (DCCU) — The DCCU provides control and timing signals to the FFG and RAUs. It accepts channel address from the FFG and transmits them to the RAUs.

### 7.3 DATA STORAGE AND PROCESSING

#### Magnetic Tape Recorders

The primary storage devices are magnetic tape recorders. Three basic types of recorders will be available. The characteristics of each type of recorder is as follows:

#### 1. Large Volume Commercial Type Adapter to Space Use

- Tape Speed — 60 inches/sec
- Tape Width — 1 inch

- Number of tracks — 28
- Packing Density — 20,000 bits/inch/track
- Reel Capacity: 10-1/2 inches — 4600 ft  
14 inches — 9200 ft

## 2. Medium Capacity

- Tape Speed-Up to 60 inches/sec
- Tape Width — 1 inch
- Number of tracks — 14
- Packing Density — 10,000 bits/inch/track
- Reel Capacity: 10-1/2 inches — 4600 ft

## 3. Video Recorder

- Tape speed — 15 inches/sec
- Video Bandwidth — 4.25 MHz
- Recording Time — 96 min (nominal 7200 ft)

## Computer

In the Data Management Block Diagram the processor, memory and input/output (I/O) make up the digital computer. Its primary function is experiment control and sequencing through coordinate conversions and data correlation. Also, some data reduction may be done for quick look analysis.

Typical performance characteristics are as follows:

Word Length: 16 bits

Memory Size: 16k × 16 bit words

Speed: Typical add time of 2-4 sec

Instructions: Typical minicomputer instruction set including multiply, divide, fixed and floating point.

Software: Fortran compiler, assembler, emulator and diagnostic routines.

#### 7.4 DATA SEQUENCING AND CONTROL

The data management system will receive and can display state vector information from the Shuttle. This will include position, velocity, body rates and attitude, time, altitude, and other selected data as required by the experiments. This data will be utilized by the data management system or the experiments as necessary for support.

All sequencing, control, and computation support required by the experiments will be defined and implemented in the data management system. Coordinate transformations required for instrument pointing will be performed by data management. In general, this will be done primarily by software in the DCCU and/or computer.

#### 7.5 COMMUNICATIONS

All communications shall be through the Shuttle communications system via standard Lab interfaces. Requirements exceeding this capability will be handled by equipment added to the Sortie Lab. The following capabilities will be available to the Sortie Lab through the Shuttle:

- Two-way voice communications between the payload bay and the Shuttle.
- Conference capability with the ground shall be provided during periods of communication coverage.
- Twenty-five thousand bits per second (BPS) total digital data allocation to be shared by all payloads when interleaved with Orbiter downlink data and 256,000 BPS via hardware input to the Orbiter telemetry encoder, when no Orbiter data are transmitted.
- Wideband data — A hardwired input to the Orbiter wideband transmitter carrier shall be provided for attached payloads.

For analog data, the Sortie Lab shall provide commutation and subcarrier oscillators compatible with the Orbiter transmitter circuitry. For digital data, the payload shall provide the required encoding for compatibility with the Orbiter transmitter. This transmitter must be time shared among Orbiter downlink television, payload analog data, or payload digital data.

## 8.0 ELECTRICAL POWER

### 8.1 SUMMARY SPECIFICATIONS

Electrical power (30 Vdc) on the Sortie Lab is supplied by fuel cells. Batteries are used to supplement the power where necessary and inverters will be available to supply a.c. power. The power network will have the capability to connect to the Shuttle power system for distribution of Shuttle-furnished power.

Power distribution is provided to each end of the module and to the pallet when it is attached through two Mission Peculiar Equipment (MPE) distributors provided for experiment power management. The MPE distributors can be configured for a particular mission from a selection of government furnished circuit breakers, current monitors, and solid state power distribution modules. Alternately, experimenter furnished distributor assemblies can be inserted in standard racks.

### 8.2 SYSTEM SIZING

The power system can be sized according to mission power requirements. Reactant tanks can be added or subtracted for different energy requirements. The scaling for a 7-day mission is shown in the Power System Weight curve, Figure 3-47 below.

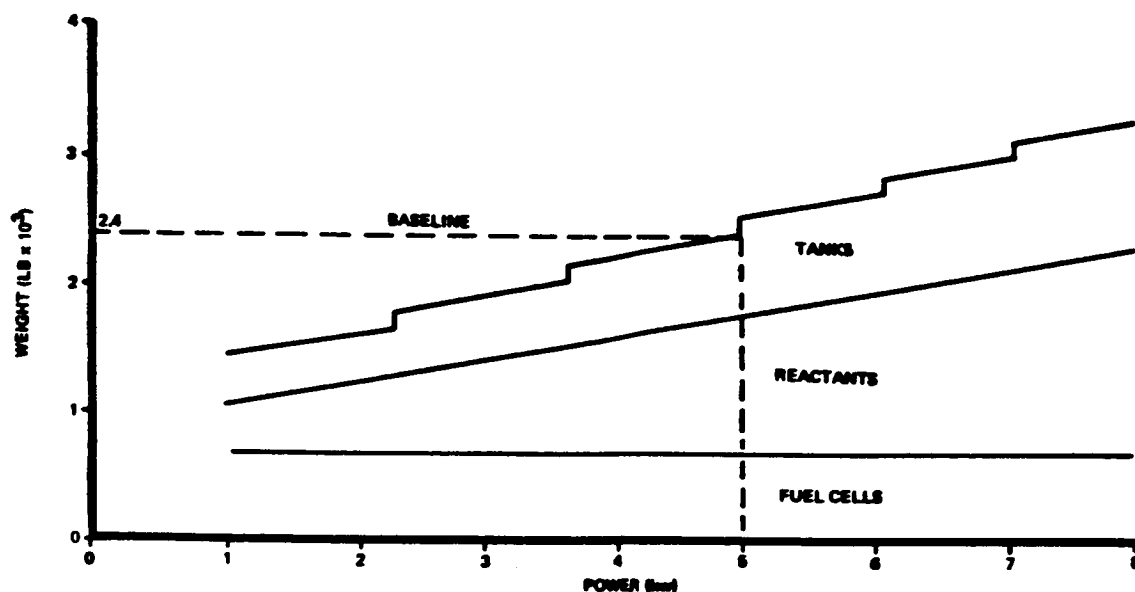


Figure 3-47. Power System Sizing

### 8.3 TYPICAL POWER ALLOCATIONS

The division of power between the various subsystems (many providing direct experiment support) and experiments is shown in the Power Requirements chart, Figure 3-48 below, for on-orbit operations.

	<u>Power Watts</u>		<u>Power Watts</u>
<u>RACK NO. 116</u>		<u>RACK NO. 113 (continued)</u>	
MONITOR	20	TV XMTR	100
POWER DISTR.	20	PRINTER	20
INVERTER LOSS	30	VIDEO TAPE	100
	<u>70</u>		<u>330</u>
<u>RACK NO. 111</u>		RAU (10)	40
MONITOR	20	IU (3)	30
TAPE	230	EXP. TABLE (200)*	<u>70</u>
NETWORKS	20	SPEC. POINTING (100)*	
	<u>270</u>	<u>C&amp;D (SUBSYSTEM)</u>	
<u>RACK NO. 114</u>		CRT (2) (PROCESSOR)	446
MONITOR	20	KEYBOARD (2)	16
TAPE	76	DEDICATED	34
CENTR. PROC. & MEMORY	8	HAND CONT. (2)	20
I/O	5	TV (2)	<u>24</u>
DCU	20		<u>540</u>
INTERCOM	30	C&D (EXPERIMENTS)	200
TABLE ELECT (100)*	<u>159</u>	LIGHTING	180
<u>RACK NO. 113*</u>		TCS/EC	<u>1,000</u>
MONITOR	20	TOTAL SUBSYSTEM	<u>2,489</u>
VHF XCVR	25	EXPERIMENTS	<u>1,500</u>
S-BAND XCVR	35		<u>3,989</u>
PRE-MOD PROC	15	LOSSES - 10%	<u>399</u>
TV RCVR	15		
		TOTAL ELECT POWER	<u>4,388</u>

\*Add-on equipment not included in Tab.

Figure 3-48. Power Requirements

The equipment in the tabulation is typical for the type missions that have been studied to date. The data can be summarized as follows:

Experiment	1700W
Electrical Support	1000W
Lighting and Thermal Control	1200W

For power during ascent and descent, the Space Shuttle provides up to 1.0kW average and 1.5kW peak which will be distributed by the Sortie Lab network to provide experiments and subsystems with that power necessary for safety status monitoring, thermal control, or other required functions.



#### 8.4 REPRESENTATIVE POWER PROFILES (ON-ORBIT)

Representative ranges for experiment power requirements are shown in the power profile chart, Figure 3-49, for sample missions labeled as Missions 8 and 10. For both missions the subsystem power is 2900W including power system losses.

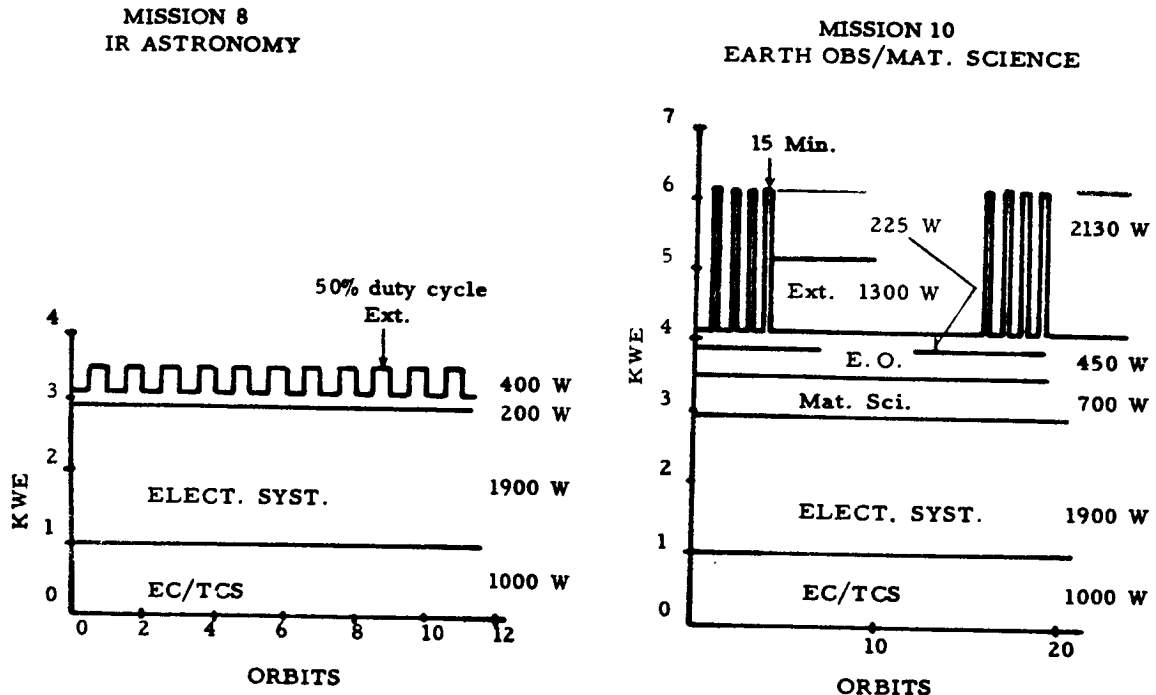


Figure 3-49. Power Profile

#### 9.0 STABILIZATION

Many experiments will require tracking capability, multiple pointing directions, pointing accuracy, stability levels and jitter rates well beyond the capability of the basic or an improved Shuttle control system. Such experiments may have internal optical stabilization or individual tables to meet their particular requirements. This is an especially satisfactory arrangement when the experiments need to be in or near the pressurized experiment laboratory. However, a general experiment platform is planned with the capability for precision pointing (about 1 arc sec) of several small experiments or a single very large experiment.

Figure 3-50 illustrates the experiment table which should meet objectives discussed in the previous paragraph. It has a conventional gimballed torquer controlled inner ring that provides control about two axes. This stabilizes the line-of-sight with roll about the line-of-sight depending on the Shuttle airframe stability. It is envisioned that experiment packages up to 10 feet in diameter and 15 feet or longer, weighing several thousand pounds, could feasibly be accommodated. The experiment could be placed in the inner gimbal ring with its long axis aligned with the long axis of the bay. The gimbal torquers could then rotate the experiment out of the bay for the observations.

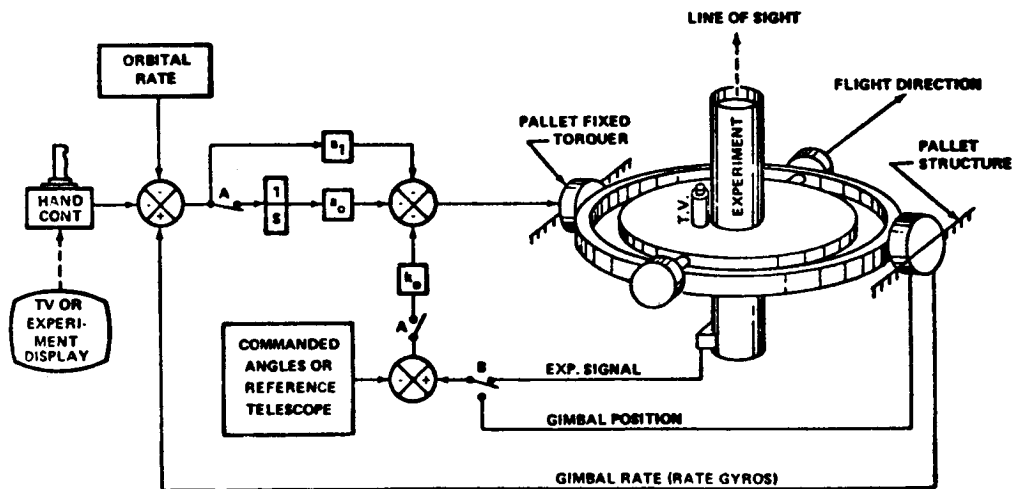


Figure 3-50. Experiment Table Concept

The signal flow is shown in Figure 3-50 to illustrate some of the flexibility and convenience that the table can furnish to the experimenter. The gimbal rate loop, with switch A as shown, provides the torquer commands to inertially stabilize the experiment base and isolate it from Shuttle motions. An orbital rate can be applied for stabilizing the line-of-sight to a point on the surface of the earth. The hand controller can be used for target acquisition and trim commands based on the display from a table-mounted TV or an experiment. When switch A is in its alternate position, the table can be positioned directly by an experiment error signal with damping provided by the gimbal rate loop. When switch B is also in its alternate position, the table will be driven to reposition its gimbals to zero, or slaved to any other instrument or pointing direction specified by a set of two Euler angles.

Table 3-6 gives the estimated pointing errors for experiments which are controlled by the table. The Shuttle data given are very preliminary (representative) and subject to revision based on Shuttle system definition. The table with nominal preparation refers to the fact that no special attempt was made to balance the load other than a reasonably symmetrical mounting of experiments on the inner gimbal ring (c.g. error of  $\pm 2$  in.). This primarily affects jitter rate. The case for which the gimbal error signal is obtained from a sensor mounted on the inner gimbal results in a large reference error of about 1 arc min. The table which has precision balanced loads (c.g. error of  $\pm 0.4$  in.) and a good error signal directly from the experiment can probably achieve a pointing accuracy below 1 arc sec and a jitter rate of about 1 arc sec/s. Any pointing requirement which exceeds these values must be supplied by internal control of experiment optics.

## 10.0 ENVIRONMENTAL CONTROL/LIFE SUPPORT

### 10.1 GENERAL SYSTEM

The baseline Sortie Lab EC/LSS is designed to accommodate, on-orbit, a nominal crew of two to four for a mission duration of seven days. Two additional crewmen can be accommodated for a limited duration. A two gas sea level equivalent atmosphere (i.e., 14.7 psia, 80 percent nitrogen, 20 percent oxygen) is provided within the module. Sufficient makeup is available for one airlock repressurization per 12 hour shift. Also, one repressurization of the complete Lab is provided for emergencies. Thermal control and purification and control including CO<sub>2</sub> and odor removal is also provided.

### 10.2 THERMAL CONTROL

#### 10.2.1 Thermal Environment in Sortie Lab and on Pallet

The Sortie Lab air temperature can be maintained in a selective range of 65° to 85°F. The normal operating temperature is 72°  $\pm$  5°F. The mean radiant wall temperature varies between 60° to 80°F with the surface limit not exceeding 113°F.

Crew comfort requirements are based on an expected range of crew activity commensurate with 400 to 600 Btu/hr/man. The crew comfort zone is defined employing minimal restraints on the thermal control system by using variable cabin air velocities

Table 3-6  
Pointing Errors (Preliminary)

Control Technique	Sensor Location	Error Types			
		A Reference	B Stability	Pointing A + B	Jitter Rate
<ul style="list-style-type: none"> <li>Shuttle ACPS:</li> <li>Large Thrusters</li> <li>Small Thrusters</li> </ul>	Shuttle GN & C Shuttle GN & C Experiment Fixed	$\pm 0.5^\circ$ $\pm 0.5^\circ$ $\pm 0.1^\circ$	$\pm 0.5^\circ$ $\pm 0.1^\circ$ $\pm 0.1^\circ$	$\pm 1.0^\circ$ $\pm 0.6^\circ$ $\pm 0.2^\circ$	$\pm 0.1^\circ/\text{s}$ $\pm 0.01^\circ/\text{s}$ $\pm 0.01^\circ/\text{s}$
<ul style="list-style-type: none"> <li>CMG's:</li> <li>Skylab Application</li> <li>Shuttle Application</li> </ul>	Skylab Rack Internal to Exp.	$+0.1^\circ$ Negligible	$\pm 0.02^\circ$ $\pm 0.02^\circ$ ( $\pm 72$ sec)	$\pm 0.12^\circ$ $\pm 0.02^\circ$ ( $\pm 72$ sec)	$\pm 0.0167^\circ/\text{s}$ $\pm 0.01^\circ/\text{s}$ ( $\pm 36$ sec/s)
<ul style="list-style-type: none"> <li>Experiment Table:</li> <li>Nominal Preparation</li> <li>Precision Balancing</li> </ul>	Inner Gimbal Internal to Exp.	$\pm 60$ sec Negligible	$\pm 2.5$ sec $\pm 0.5$ sec	$\pm 62.5$ sec $\pm 0.5$ sec	$\pm 5$ sec/s $\pm 1$ sec/s

• Errors which result from roll about line of sight will be a function of vehicle airframe stability.

and various types of clothing for expected metabolic ranges. Maintaining environments in the comfort envelope will allow transient periods of work at much higher rates without discomfort.

The nominal cabin sensible and latent heat load of 8131 Btu/hr is utilized in the atmospheric processing (temperature and humidity control).

Experiments located on the pallet are subject to the thermal environment of the payload bay. The internal wall temperature limits for the payload bay are as follow:

<u>Condition</u>	<u>Minimum</u>	<u>Maximum</u>
Prelaunch	40°F	120°F
Launch	40°F	150°F
On-Orbit (door closed)	-100°F	150°F
On-Orbit (door open)	—	—
Entry and Postlanding	-100°F	200°F

#### 10.2.2 Thermal Control Provisions for Experiments

The Sortie Lab provides an active thermal control system during all mission phases. Thermal conditioning is provided during ascent and descent by heat rejection to an expendable heat sink. For on-orbit operations, the active thermal control system rejects heat from the crew, Sortie Lab subsystems, the fuel cell, and the experiments.

A Sortie Lab undeployed from the bay (nominal operating position) has approximately 266 ft<sup>2</sup> radiator which can be supplemented with thermal capacitors for certain orientations and mission equipment combinations while operating on the sun side of the orbit. Also, for some high inclination orbits where the orbital heat load remains constant, an expendable heat sink is required.

A deployed Sortie Lab (rotated 90 degrees out of the payload bay) has sufficient available radiator areas to reject all anticipated heat loads.

The Lab internal design heat load is 18561 Btu/hr which includes 5120 Btu/hr for experiments. This experiment heat load is

dissipated to a sink which is at a temperature between 73°F to 99°F.

For thermal control in the Lab, experiments and experiment support equipment shall be mounted on standard cold plates or air cooled. Pallet mounted experiments may be thermally controlled either passively or by an active thermal control loop mounted on the pallet, depending on the quantity of heat to be dissipated.

### 10.3 CONTAMINATION AND CONTROL PROVISIONS

The Sortie Lab internal environment is planned to be maintained at a particle contamination Class 100,000, with Class 10,000 localized work stations added when required on particular missions. Principal contamination control features are the inlet manifold with multiple filtered registers, a trace contaminants shall be controlled to 15 PPM or less. The primary air flow will allow one air change per three minutes.

The Class 10,000 work station required for some experiments can be configured in a cabinet sized unit with air entering at the top under the action of a fan, flowing through an appropriate HEPA filter downward to a grating work surface. Air leaves through the bottom of the cabinet, is pulled through a baffle arrangement by a fan and exhausts into the Sortie Lab. A typical arrangement is shown in Figure 3-51.

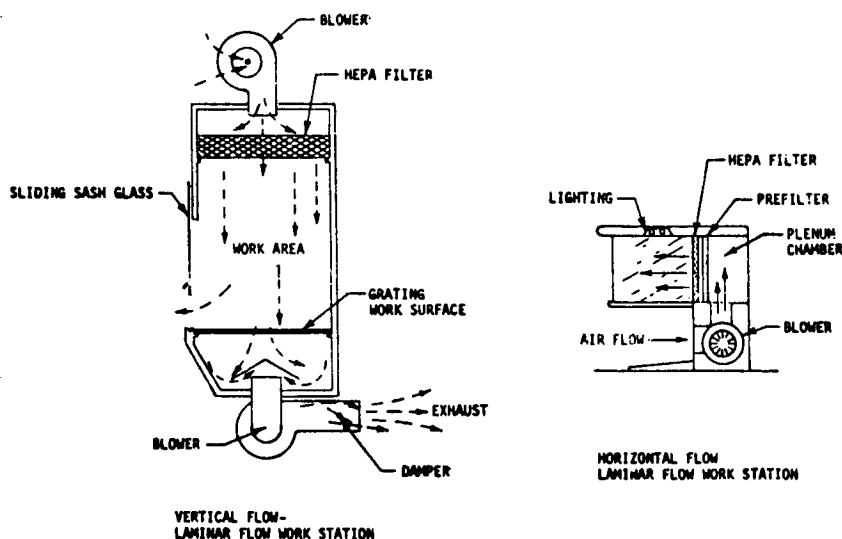


Figure 3-51. Local Contamination Control

## 11.0 CREW SYSTEMS

### 11.1 CREW SIZE

The normal Shuttle crew is comprised of a crew of four of which two will be mission specialists available to payload operations and well trained in payload operations. Complete habitability provisions for the normal crew of four will exist in the pressurized volume of the Shuttle flight deck. The habitability provisions will accommodate both male and female personnel. The Shuttle and Sortie Lab will be designed to support a larger crew complement of at least two additional personnel as mission operations demand. The specific scheduling and utilization of the larger crew sizes is to be determined.

It is the intent to make the near earth space environment directly accessible to the broadest possible spectrum of users within the government, industry, and university communities. The Sortie Lab is therefore being developed to permit operations as nearly analogous as possible to those in an earth-based laboratory, and to move toward flight by non-pilot-trained personnel. Planning at this time has not progressed sufficiently to determine specifically the types of personnel who would be considered as the mission or payload specialists operating within the Sortie Lab during the early years of operation. These individuals may be scientific personnel without piloting background, regular flight personnel trained for the specific mission, or combinations of these.

### 11.2 CREW SCHEDULES

Habitability provisions aboard the Orbiter and Sortie Lab will be designed to permit either simultaneous or staggered work/rest cycles. It is therefore possible to arrange the time line for a particular mission with considerable flexibility to maximize the return from the payload.

The Orbiter commander and pilot shall not be considered available to assist in normal payload operations. Likewise, the scientific crew is not required to assist in normal Orbiter operations except those directly relating to payload operations or interface control. For planning purposes, each scientific crewman will be able to devote up to 10-12 hours per day to payload operations for short-duration (7-day) missions. The remainder of each day will be required for eating, sleeping, personal hygiene, etc.

### 11.3 REPRESENTATIVE CREW FUNCTIONS AND ROLE

Crew activities within the Sortie Lab will include management of the autonomous Lab systems for electrical power, environmental control and life support (ECLS), thermal control, and utilization of other expendables. The crew will also be responsible for the setup and activation of experimental equipment after orbit is achieved, for nominal operation of experiments, for monitoring the performance of that equipment; and for preparing that equipment for reentry at the conclusion of the mission. The scientific crew will also be responsible for the operation of mission peculiar equipment such as stable platforms, scientific airlocks, etc.

EVA, as required in support of payload operations, will be performed by specially trained crewmen. The training required for EVA is more extensive than the training which will normally be given the scientific crewmen. For those missions requiring EVA, two EVA trained crewmen will be required.

### 11.4 CREW TRAINING

Although crew training requirements cannot be finalized at the present time, it is expected that crewmen for early Sortie missions will receive fairly extensive training in the operation of the science payload as well as general operation of the Lab. General training will potentially include development of a thorough understanding of Sortie Lab systems and demonstration of proficiency in operating those systems, a limited introduction to Orbiter operations, familiarization with zero-gravity flight through participation in neutral buoyancy activities and Keplerian-trajectory zero-gravity flight, and practice in operating the planned scientific and data-recording equipment in earth-based Sortie Lab simulators. Training will also include actual practice with pre-takeoff and post-landing emergency egress procedures, and actual practice with inflight emergency procedures such as use of lightweight pressure suits and oxygen masks, fire suppression, etc.



## ATTACHMENT II

### SORTIE LAB

#### GUIDELINES AND CONSTRAINTS

##### LEVEL I

##### PREFACE

Attachment II presents the top level (headquarters imposed) guidelines and constraints to be used in the course of the program definition study just getting underway on Sortie Lab. Consequently, the material in the second attachment represents more recent thinking than that in the first attachment, but this material is also very preliminary and can and will be changed when good reasons appear.

# SORTIE LAB LEVEL I GUIDELINES AND CONSTRAINTS

## REVISION NO. 1

### 1.0 PROGRAMMATICS

#### 1.1 DEFINITIONS

- 1.1.1 Sortie Lab Project includes the definition, design, development and operations of manned payload carriers, unpressurized instrument platforms (pallets), experiment support apparatus, and the interface equipment needed to interconnect and maintain the pallet and/or the Lab to Shuttle interface. The project also includes ground operations involving experiment integration-checkout-test, carrier refurbishment, control center and information networks, and on-orbit operations associated with carriers and their data gathering systems.
- 1.1.2 A Sortie Lab is a manned laboratory suitable for conducting research and applications activities on Shuttle sortie missions transported to and from orbit in the Shuttle payload bay and attached to the Shuttle orbiter stage throughout its mission. The Sortie Lab will be characterized by low cost versatile laboratory facilities, rapid user access, and minimum interference with the Shuttle orbiter turn-around activities. Unless specifically stated the Sortie Lab includes an attached unpressurized instrument platform called a Pallet.
- 1.1.3 A Pallet is an unpressurized platform for mounting telescopes, antennae and other instruments and equipment requiring direct space exposure for conducting research and applications activities on Shuttle sortie missions.
- A pallet will normally be attached to a Sortie Lab with the pallet experiments being remotely operated from the Sortie Lab. A pallet can also be attached directly to the Shuttle orbiter and operated from the orbiter cabin.
- 1.1.4 Baseline is defined as a fundamental point of reference with regard to project plan, configuration, operations and experiments and will serve as the basis for comparison of alternatives.

## 1.2 PROJECT PLANNING

- 1.2.1 The baseline plan will include a flight unit of the Sortie Lab including a pallet outfitted with experiments in time for use on a Shuttle flight in mid 1979.
- 1.2.2 The baseline plan will include a prototype of the Sortie Lab including a pallet sufficiently in advance of the flight date to be the primary facility for total system qualification and also for crew training, experiment integration practice, and mission simulation.
- 1.2.3 The baseline plan will include sufficient numbers of flight modules pallets, racks, and experiment support equipment to allow for orderly and timely checkout and test of experiments/carriers and carrier installation into the shuttle.

## 1.3 ENVIRONMENT

- 1.3.1 Natural environment data as specified in NASA TMX 64668 will be used for design and operational analyses.
- 1.3.2 The environments experienced by Sortie Lab and/or pallet associated with ground handling and ground and flight operations are contained in the following documents (TBD).

## 2.0 SYSTEMS

### 2.1 DESIGN MISSIONS

- 2.1.1 Sortie Lab will be designed for three classes of missions:
  - I. Experiment Missions supporting both multidiscipline and single discipline research and applications. The baseline duration of experiment missions will be 7 days. Extended duration of experiment missions will be up to 30 days. Polar orbit capability will be provided.
  - II. Servicing Missions providing on-orbit maintenance and equipment change-over support to automated man-tended free-flying spacecraft.
  - III. Development Missions in support of Shuttle/Sortie Lab development and of the determination of payload environments.

The development missions are to be considered secondary design drivers.

## 2.2 DESIGN LIFE

- 2.2.1 The Sortie Lab will be designed for an operational life of at least 50 missions of 7 days duration with ground refurbishment.

## 2.3 MISSION SUCCESS

- 2.3.1 The Sortie Lab will be designed for a high probability .95 of mission success. Mission success will be measured by proper functioning of the module, its systems and subsystems, and experiment support equipment provided to the user. This level of mission success will be assured by component and subsystem reliability, redundancy and on-board maintenance as appropriate. Mission success does not require successful completion of all experiments.
- 2.3.2 The Sortie Lab subsystems designs will be based on at least a fail safe concept except for the structure which will be based on a safe life concept. Subsystem redundancy will only be used to achieve mission success and fail safe design goals or to reduce cost.

## 2.4 CREW SIZE

- 2.4.1 For design of the Sortie Lab, the following numbers of personnel shall be considered:

	<u>Total in Orbit</u>	<u>Payload Dedicated*</u>
Baseline	6	4
Maximum	8	6
Minimum	4	2

\*Note that these numbers assume that "payload dedicated" personnel will spend most of their work time on experiments, experiment support equipment and Sortie Lab subsystems. If shuttle operations on orbit require more than two crewmen for most of their work time, the corresponding numbers for "total in orbit" will increase and weight attributable to the larger crew will be chargeable to Sortie Lab.

The Shuttle Orbiter will provide sleep, galley, waste management and personal hygiene accommodations. The weight of all payload dedicated personnel in excess of two including the weight of their seats, equipment and provisions will be chargeable to Sortie Lab.

## 2.5 WEIGHT

- 2.5.1 The total weight of the Sortie Lab, the pallet when used, the experimental apparatus, expendables and other necessary devices chargeable to Shuttle payload, all with suitable design weight margins, shall not exceed 80% of the Shuttle nominal performance for the particular mission of interest.

## 2.6 MARGINS

- 2.6.1 Where applicable, safety factors and design margins will be sufficiently large to minimize a costly verification and qualification effort. Specific values will be established by level 2 guidelines.

## 2.7 AUTONOMY (Level of Shuttle Support)

- 2.7.1 The Sortie Lab will make efficient use of Shuttle-provided utility support (i.e. power, communications, environmental control, etc.) consistent with a simple module to orbiter interface and with minimum mutual interference during turn-around activities.

## 2.8 SUBSYSTEMS

- 2.8.1 Where cost effective, available subsystems, assemblies, and components will be used in the Sortie Lab, the pallet and all necessary non-Shuttle flight and ground support equipment. These items include standard commercial components and those developed for other programs including the Shuttle. Availability of the suppliers is an important consideration.

## 2.9 GROWTH

- 2.9.1 The baseline Sortie Lab will include design provisions, if cost effective, for growth in experiment support requirements on 7 day missions (e.g. space and connections for additional assemblies and tankage). The Sortie Lab will also include design provisions, if cost effective, for growth in mission duration up to 30 days.

### 3.0 OPERATIONS

#### 3.1 MISSION OPERATIONS

The baseline assumption for mission operations for Sortie Lab is that communications and mission control will be through the Mission Control Center at MSC.

#### 3.2 COMMUNICATIONS NETWORK

The characteristics of the communications systems with the earth, as a function of operational date, are described in: "Characteristics of Future Ground Network and Synchronous Satellite Communications System for Support of NASA Earth Orbital Missions (for Planning Purposes Only)," OTDA, September 1972 issue.

#### 3.3 DATA MANAGEMENT

The baseline assumption for the definition and management of data acquisition, processing and handling is that they will be the responsibility of MSFC.

#### 3.4 EXPERIMENT PAYLOAD INTEGRATION

The baseline assumption for experiment payload integration is that it will be the responsibility of MSFC, but will be carried out in many cases at off-site locations including KSC and various user facilities (other NASA centers, other government laboratories, universities, industrial concerns, foreign users, etc.). This integration may be at the black box, birdcage rack or complete pallet or module level.

#### 3.5 MISSION PREPARATION

The baseline assumption for prelaunch mission preparation, including Sortie Lab refurbishment, final experiment payload integration, prelaunch crew training, hardware and software mission compatibility, verification and checkout, is that it will be carried out at KSC.

## 4.0 INTERFACE

### 4.1 SHUTTLE INTERFACE

4.1.1 The baseline Shuttle to payload interfaces will be defined by the following documents:

- (a) Space Shuttle Program Requirements Document Level I dated April 21, 1972, Revision No. 4
- (b) Space Shuttle Baseline Accommodations for Payloads MSC — 06900 dated June 27, 1972.

A standardized interface concept will be jointly developed with the Shuttle program.

### 4.2 USER PROVISIONS

- 4.2.1 Laboratory utility to the users will be a major consideration in all design and operational concept decisions (see 7.1).
- 4.2.2 As a goal the facilities provided by the Sortie Lab will accommodate user's research and applications apparatus with minimum costs to the users for modification or adaptation.
- 4.2.3 Near continuous voice communication will be available between on-board experimenters and their colleagues on the ground. Supplementary capability for wideband data and spacecraft to ground TV will be provided.

## 5.0 EXPERIMENTS

- 5.1 Experiment requirements as determined by the special study and workshop activities established to define sortie missions shall be a major input and source of design trade studies.

## 6.0 SAFETY

- 6.1 A system safety plan shall be developed in accordance with NASA Safety Program Directive No. 1 (Rev A) dated December 12, 1969, and other applicable directives (TBD). Compatibility with applicable shuttle safety directives is required.

6.2 No credible hazard associated with the Sortie Lab or its experiment activities shall prevent safe termination of a mission.

6.3 The Sortie Lab shall have self-contained protective devices or provisions against all credible hazards generated by its support functions or experiment activities.

6.4 EVA (Extra Vehicular Activity) will be minimized in all equipment operations.

## 7.0 RESOURCES

### 7.1 COST

7.1.1 Low initial and total cost is a major objective of the Sortie Lab Project.

7.1.2 The cost impact will be a major consideration in all major design and operational concept decisions.



## **APPENDIX A**

### **REVISED LIST OF WORKING GROUPS**

# REVISED LIST OF WORKING GROUPS

GROUP NAME	CHAIRMAN	CO-CHAIRMAN
IR Astronomy	Mr. M. Dubin (Hq.)	Dr. L. Caroff (ARC)
Optical Astronomy	Dr. N. Roman (Hq.)	Dr. S. Sobieski (GSFC)
Solar Physics	Dr. G. Oertel (Hq.)	Mr. K. Frost (GSFC)
X-ray Astronomy	Dr. A. Opp (Hq.)	Dr. C. Fichtel (GSFC)
High Energy Cosmic Ray Physics	Dr. A. Schardt (Hq.)	Dr. F. McDonald (GSFC)
Atmospheric and Space Physics	Dr. E. Schmerling (Hq.)	Mr. W. Roberts (MSFC)
Life Sciences	Dr. R. Hessberg (Hq.)	Dr. D. Winter (ARC)
Space Technology	Mr. D. Novik (Hq.)	Mr. R. Hook (LaRC)
Planetary Astronomy	Dr. W. Brunk (Hq.)	Dr. R. Hanel (GSFC)
Communications & Navigation	Mr. E. Ehrlich (Hq.)	Mr. C. Quantock (MSFC)
Earth & Ocean Physics Applications	Mr. B. Milwitzky (Hq.)	Dr. F. Von Bun (GSFC)
Earth Resources and Surface Environmental Quality	Dr. A. Park (Hq.)	Mr. C. Paludan (MSFC)
Meteorology and Atmospheric Environmental Quality	Mr. W. Spreen (Hq.)	Mr. W. Bandeen (GSFC)
Oceanography	Dr. M. Tepper (Hq.)	Mr. H. Curfman (LaRC)
Materials Processing and Space Manufacturing	Dr. J. Bredt (Hq.)	Dr. B. O. Montgomery (MSFC)

## APPENDIX B

### WORKING GROUP REPORT FORMAT

## APPENDIX B

### WORKING GROUP REPORT FORMAT

#### DISCIPLINE WORKING GROUP PRELIMINARY REPORT

1. Discipline area
2. Outline the goals and objectives for the discipline for the decade of the 1980's.
3. Identification of the potential contributions the sortie mode can make to specific discipline goals and objectives.
  - a.
  - b.
  - c.
  - etc.

4. Descriptive title of sortie mission or missions required for each of the potential contributions listed in #3 above (not necessarily all different).
  - a.
  - b.
  - c.
  - etc.
5. Descriptive titles of sortie missions for which requirements and characteristics are outlined in attached appendices.
  - a.
  - b.
  - c.
  - etc.
6. Outline of the proposed total flight schedule of sortie and non-sortie missions needed to meet the discipline goals and objectives.

1979

1980

1981

1982

1983

1984

1985

1986

1987

1988

1989

1990

APPENDIX \_\_\_\_\_

- A. Discipline area
  
  
  
  
  
  
  
  
  
  
- B. Sortie descriptive title
  
  
  
  
  
  
  
  
  
  
- C. Reasons the sortie mode would be preferred over other methods for each of the potential contributions of this type sortie mission given in #4.

D. Requirements this type mission places on the shuttle if the potential contributions are to be realized.

- (1) Length of flights
- (2) Orbit
- (3) Data requirements
- (4) Role and number of personnel in orbit
- (5) Stabilization and pointing
- (6) Power and thermal
- (7) Weight and volume
- (8) EVA requirements
- (9) Correlative measurements
- (10) General support equipment
- (11) Documentation requirements
- (12) Special operating constraints
- (13) Contamination requirements
- (14) Other

- E. Policies and procedures which must be changed or instituted to fully exploit the shuttle sortie mode and reduce the cost of research in space.
- F. Brief description of estimated magnitude of sortie mission user community.
- G. Recommended approaches for interfacing with the user community.
- H. Recommendations on future actions required to implement the sortie mission including SRT, studies, and future planning activities.



APPENDIX C

SYMPOSIUM AGENDA

APPENDIX C  
SYMPOSIUM AGENDA

AGENDA

Monday, July 31, 1972

WELCOME

Mr. Donald P. Hearth, Deputy Director  
Goddard Space Flight Center

AGENCY PROGRAM OVERVIEW

Dr. George M. Low  
Deputy Administrator, NASA Hq

Dr. John E. Naugle, Associate Administrator  
Office of Space Science, NASA Hq

Mr. Charles W. Mathews, Associate Administrator  
Office of Applications, NASA Hq

SPACE SHUTTLE OVERVIEW

Mr. Jack C. Heberlig  
Space Shuttle Program Office, MSC

SORTIE MISSION DESIGN & TRAJECTORY ANALYSIS

Mr. Kenneth A. Young  
Mission Planning & Analysis Div., MSC

BASELINE INTERFACE ACCOMMODATIONS FOR PAYLOADS

Mr. Hubert P. Davis  
Payloads Engineering Office, MSC

PAYLOADS HANDLING AT THE SHUTTLE LAUNCH SITE

Mr. H. E. McCoy  
Launch & Landing Operations Office, KSC

OPERATIONS AND MISSION CONTROL

Mr. Charles A. Beers  
Flight Operations Directorate, MSC

FLIGHT CREW INTEGRATION FOR SHUTTLE/PAYLOADS

Mr. Samuel H. Nassiff  
Flight Crew Integration Div., MSC

Tuesday, August 1, 1972

SORTIE MODULE DEVELOPMENT & SUPPORTING ACTIVITIES

Mr. Douglas R. Lord, Director  
Space Station Task Force, NASA Hq

EXPERIMENTAL/SORTIE LABORATORY EXPERIMENT INTERFACES

Mr. William R. Marshall, Chief  
System Design & Integration Div., MSFC

SHUTTLE PAYLOAD PLANNING & DESIGN DATA

Mr. Harry G. Craft  
Applications & Technology Group, MSFC

CV-990 ANALOG & SORTIE MODE SIMULATION

Mr. Donald R. Mulholland, Chief  
Airborne Science Office, ARC

GENERAL PURPOSE & DEDICATED LABORATORY CONCEPTS  
FOR SORTIE MODE

Mr. William T. Carey  
Applications & Technology Group, MSFC

## ADVANCED TECHNOLOGY LABORATORY FOR SORTIE MODE

Mr. W. R. Hook  
Space Systems Div., LaRC

Wednesday, August 2, 1972

### Working Group Meetings

Thursday, August 3, 1972

### Working Groups Results

Space Technology	R. Hook	LaRC
Materials Processing and Space Manufacturing	B. Montgomery	MSFC
Communications and Navigation	E. Ehrlich	Hq
Earth & Ocean Physics Applications	B. Milwitsky	Hq
Oceanography	H. Curfman	LaRC
Earth Resources and Surface Environmental Quality	A. Park	Hq
Meteorology and Atmospheric Environmental Quality	W. Spreen	Hq
Life Sciences	R. Hessberg	Hq
Applications Summary	C. Mathews	Hq
Atmospheric and Space Physics	E. Schmerling	Hq
Solar Physics	G. Oertel	Hq
High Energy Cosmic Ray Physics	A. Schardt	Hq
X-Ray Astronomy	A. Opp	Hq
Optical Astronomy	N. Roman	Hq
Planetary Astronomy	W. Brunk	Hq
IR Astronomy	M. Dubin	Hq
	&	
	W. Hoffman	Hq
Space Shuttle Summary	J. Heberlig	MSC
Space Sciences Summary	J. Naugle	Hq

Friday, August 4, 1972

EXECUTIVE SESSION INCLUDING

Attendance

Chairmen  
Co-Chairmen  
Organizing Committee

Agenda

Critique of Symposium  
Proposal for Subsequent Meetings  
Charter Document  
Adjournment

**APPENDIX D**

**MILESTONE SCHEDULE**

## APPENDIX D

### MILESTONE SCHEDULE

#### FY 73 SORTIE PLANNING MILESTONES

- |   |               |
|---|---------------|
| 1. Establish in-house discipline working groups to start the sortie mission planning                      | Jul 72        |
| 2. Conduct an in-house workshop with shuttle program representatives and the discipline working groups    | 31 Jul-4 Aug  |
| 3. Initial working group reports due  | 18 Aug        |
| 4. Schedule for subsequent working group meetings due   | 18 Aug        |
| 5. Proposed working group membership including non-NASA people due  | 18 Aug        |
| 6. Publish proceedings of the in-house workshop   | 15 Sep        |
| 7. Definition of content and format of required working group reports                                     | 15 Sep        |
| 8. Interim reports from the discipline working groups due   | 1 Nov         |
| 9. Coordination of interim reports with the shuttle program   | 15 Nov        |
| 10. Guidance to the discipline working groups on consolidations or modifications required                 | 15 Nov        |
| 11. Discipline working group documentation of the recommended sortie mission program and requirements due | 15 Jan 73     |
| 12. Coordination of working group final reports with the shuttle program                                  | 15 Jan-15 Feb |
| 13. Definition of additional specific studies and reports required prior to NASA/NAS summer study         | 15 Feb        |
| 14. Continuing implementation and review of applicable study effort by working groups                     |               |

## APPENDIX E

### PARTICIPANTS



APPENDIX E  
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August 31, 1972

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